COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-069/CENIPA/2022

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PP-MCJ**
MODEL:	**206B**
DATE:	**05JUN2022**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination, and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted considering the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the distinct factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Final Report has been made available to the ANAC and the DECEA so that the technical-scientific analyses of this investigation can be used as a source of data and information, aiming at identifying hazards and assessing risks, as set forth in the Brazilian Program for Civil Aviation Operational Safety (PSO-BR).

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with Appendix 2, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Considering the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This is the Final Report of the 05 June 2022 accident with the model 206B aircraft, registration marks PP-MCJ. The occurrence was typified as “[LALT] Low Altitude Operation”.

During a flight for the inspection of electrical transmission lines, the aircraft collided with a transmission line cable and fell into a dam.

The aircraft was destroyed.

The three crewmembers suffered fatal injuries.

Being the United States of America the State of design/manufacture of the aircraft, the USA’s NTSB (National Transportation Safety Board) designated an accredited representative for participation in the investigation of the accident.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ABNT	Brazilian Association of Technical Standards
AGL	Above Ground Level
ALA	*Asociación Latinoamericana de Aeronáutica*
ANAC	Brazil's National Civil Aviation Agency
ANEEL	Brazilian Electricity Regulatory Agency
BKN	Broken clouds (5 - 7 oktas of the sky)
CB	Cumulonimbus cloud
CENIPA	Brazil's Aeronautical Accidents Investigation and Prevention Center
CHESF	*São Francisco*'s Hydroelectric Company (Brazil)
CIV	Pilot Logbook
CMA	Aeronautical Medical Certificate
CPTEC	Center for Weather Forecasting and Climate Studies (Brazil)
CRM	Crew Resource Management
CU	Cumulus cloud
DECEA	Department of Airspace Control (Brazil)
CVA	Airworthiness-Verification Certificate
DOSPA	*Paulo Afonso*'s Aviation Division
EASA	European Union Aviation Safety Agency
ELT	Emergency Locator Transmitter
FEW	Few clouds (1 - 2 oktas of the sky)
FIR	Flight Information Region
GAMET	General Aviation Meteorological Information
GPS	Global Positioning System
HMNT	Single-Engine Turbine-Helicopter Class Rating
hPa	Hectopascal
ICA	Command of Aeronautics' Instruction
INMET	National Institute of Meteorology (Brazil)
IS	Supplementary Instruction
LABDATA	Cenipa's Laboratory for Readout and Analysis of Flight Recorder Data
LALT	Low Altitude Operation
LT	Transmission Line
METAR	Routine Meteorological Aerodrome Report
NM	Nautical Miles
NSCA	Command of Aeronautics' System Norm
NTSB	National Transportation Safety Board (USA)

OM	Maintenance Organization
PSAC	Civil Aviation Service Provider
PCH	Commercial Pilot License - Helicopter
PIC	Pilot in Command
PMD	Abbreviation in Portuguese for Maximum Takeoff Weight
PN	Part Number
PPH	Private Pilot License - Helicopter
RBAC	Brazilian Civil Aviation Regulation
REDEMET	Command of Aeronautics' Meteorology Network (Brazil)
RMK	Remarks
SACI	Civil Aviation Integrated Information System
SBMS	ICAO location designator - *Dix-Sept Rosado* Aerodrome, *Mossoró*, State of *Rio Grande do Norte*, *Brazil*)
SAE	Specialized Public Air Service Aircraft Registration Category
SBSG	ICAO location designator - *São Gonçalo do Amarante* Aerodrome (*Gov. Aluízio Alves*), *Natal*, State of *Rio Grande do Norte,* Brazil
SC	Stratocumulus cloud
SCT	Scattered clouds (3 - 4 oktas of the sky)
SGSO	Safety Management System
SIGWX	Significant Weather Chart
SIPAER	Aeronautical Accidents Investigation and Prevention System
SN	Serial Number
SPECI	Aviation Selected Special Weather Report
TAESA	*Aliança* Electric-Energy Transmission Corporation
TCU	Towering Cumulus cloud
TPP	Private Air Service Aircraft Registration Category
UTC	Coordinated Universal Time
VCSH	Showers in the vicinity
VFR	Visual Flight Rules
WAC	World Aeronautical Chart
WSPS	Wire Strike Protection System

1. FACTUAL INFORMATION.

Aircraft	**Model:** 206B **Registration:** PP-MCJ **Manufacturer:** Bell Helicopter	**Operator:** *Companhia Hidro Elétrica do São Francisco*
Occurrence	**Date/time**: 05JUN2022 – 16:36 UTC **Location:** *Sítio Tamanduá - Alto do Caboclo* **Lat.** 06°13’07”S **Long.** 036°32’34”W **Municipality – State:** *Currais Novos – Rio Grande do Norte*	**Type(s):** [LALT] Low altitude operations

1.1. History of the flight.

At 15:34 UTC, the aircraft took off from SBSG (*São Gonçalo do Amarante* Aerodrome - *Governador Aluízio Alves - Natal*, State of *Rio Grande do Norte*) destined for SBMS (*Dix-Sept Rosado* Aerodrome, *Mossoró*, *Rio Grande do Norte*) on a flight for inspection of the CHESF (São Francisco Hydroelectric Plant) 138-kV transmission line, with three POB (crew).

During the flight, the aircraft collided with a transmission line of TAESA *(Transmissora Aliança de Energia Elétrica S.A)* near the town of *Currais Novos*. Subsequently, the aircraft fell into a dam and sank (partially).

Figure 1 – View of the PP-MCJ at the accident site.

The aircraft was destroyed.

The three crewmembers of the aircraft suffered fatal injuries.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	3	-	-
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3. Damage to the aircraft.

The aircraft was destroyed.

1.4. Other damage.

The lightning-rod cable of TAESA's 230-kV transmission line broke, and fuel from the aircraft dispersed into the reservoir.

1.5. Personnel information.

1.5.1. Crew's flight experience.

FLIGHT EXPERIENCE	
	PIC
Total	Unknown
Total in the last 30 days	12:05
Total in the last 24 hours	03:50
In this type of aircraft	Unknown
In this type in the last 30 days	12:05
In this type in the last 24 hours	03:50

N.B.: according to the records of Integrated Civil Aviation Information System (SACI), the Pilot in Command (PIC) had 336 hours and 38 minutes of total flight time, and 277 hours and 37 minutes on the model of the accident aircraft.

The Investigation Committee did not have access to the PIC's CIV (Pilot Logbook). According to third-party accounts, the PIC had more than 3,300 flight hours**.**

1.5.2. Personnel training.

The PIC did his PPH course (Private Pilot – Helicopter) in 1981, at the *Aeroclube de Nova Iguaçu*, State of *Rio de Janeiro*.

1.5.3. Category of licenses and validity of certificates.

The PIC held a PCH License (Commercial Pilot - Helicopter), and a valid HMNT rating (Single Engine Turbine Helicopter Class.

1.5.4. Qualification and flight experience.

Digital CIV records indicated that the PIC had been operating the B-206B aircraft, registration PP-MCJ, since June 2012, carrying out LT inspection flights in the Northeast region of the country.

Part of the PIC's operational background developed when he started working for the operator in November 1987. In that period, according to data contained in SACI, he flew the following aircraft models: Bell 205, 206, and 212.

The last flight logged in the PIC's digital CIV dated from 04 November 2021. Notwithstanding, the Investigation Committee considered that the pilot met the criteria established in Section 21, Amendment nº 13, Subpart A, of the Brazilian Civil Aviation Regulation nº 61 (RBAC-61) , referring to recent experience, due to flights conducted in the previous ninety days, but not recorded in the logbook.

The PIC was qualified for and had experience in the type of flight.

The two inspectors had experience in inspecting LTs from the ground.

In the second half of 2020, they performed the first aerial inspections. By the date of the accident, one of the inspectors had flown approximately 21 hours dedicated to aerial inspection of LTs, having inspected the segment where the accident occurred on four occasions. Similarly, the other inspector had performed 8 hours of flight time in aerial inspections of LTs, having once inspected, on another flight, the segment in which the accident occurred.

None of the inspectors had flown with the PIC before.

1.5.5. Validity of medical certificate.

The PIC held a valid CMA (Aeronautical Medical Certificate).

1.6. Aircraft information.

The SN 4555 model 206B aircraft was a product manufactured by Bell Helicopter in 2001, and registered in the *TPP* category (Private Air Services).

The helicopter's *PMD* (Maximum Takeoff Weight) established by the manufacturer, was 1,519 kg, and the minimum crew was one pilot.

The CVA (Airworthiness-Verification Certificate) of the aircraft was valid.

The records of the airframe and engine logbooks were up to date.

The *Claro Comércio, Representações e Manutenção Aeronáuticas Ltda.* Maintenance Organization (municipality of *Paulo Afonso*, State of *Bahia*) carried out the last ("weekly" type) inspection of the aircraft on 30 May 2022. The aircraft flew 12 hours and 5 minutes after the referred inspection.

The last "100-hour" type inspection of the aircraft was carried out by the same maintenance organization mentioned above on 10 March 2022. The aircraft flew 34 hours and 25 minutes after the said inspection.

One found no evidence of failures or malfunctions of the aircraft or its components that might have contributed to the occurrence.

The aircraft had a Wire-Strike Protection System, consisting of an upper and a lower wire-cutting device. Its windshield had a deflector along its middle section (Figure 2).

Figure 2 - View of the PP-MCJ aircraft. Source: Jetphotos.net

Figure 3 shows a detailed view of the upper wire-cutter.

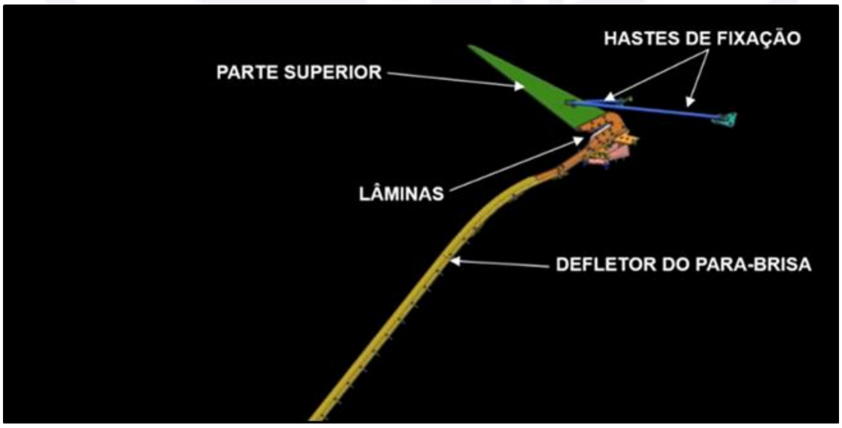

Figure 3 - Detailed view of an upper wire-cutter.

1.7. Meteorological information.

The Investigation Committee had access to messages exchanged between the PIC and members of his working group. Such messages contained information on the meteorological conditions that would affect the inspection flights scheduled for the week of the accident.

The presence of adverse weather conditions during the period of operations had already caused the cancellation of the initial flight of the aforementioned schedule, causing the aircraft to return to the municipality of *Paulo Afonso* on the morning of 31 May 2022.

The Investigation Committee used information and products available on meteorological websites for the analysis of the weather conditions on the day of the accident. The websites consulted were REDEMET (Command of Aeronautics' Meteorology Network); CPTEC (Center for Weather Forecasting and Climate Studies); INMET (National Institute of Meteorology); and GEOAISWEB (a free software system, which made aeronautical information available directly on a map, enabling its integrated use with Aeronautical Charts).

The 18:00 UTC SIGWX of 05 June 2022 (with information from the surface up to FL250, and valid from 15:00 UTC to 21:00 UTC) had the following forecast: broken cumulus and stratocumulus clouds (base at 1,700 ft and top at 6,000 ft), towering cumulus clouds (base at 2,500 ft and top at 24,000 ft), and rain showers in the area of interest (Figure 4).

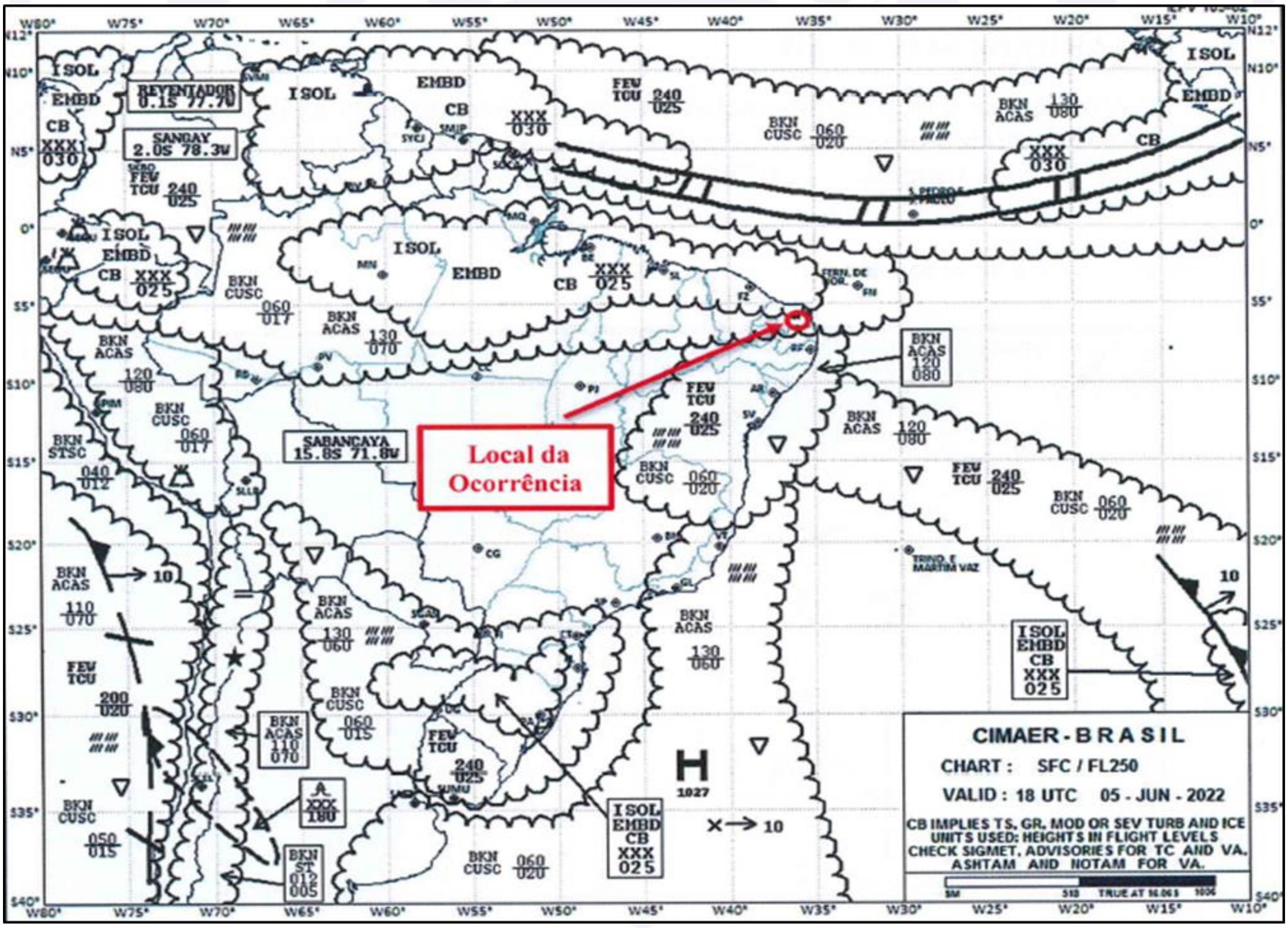

Figure 4 - SIGWX chart (from surface to FL 250). Source: REDEMET.

The 05 June 2022 GAMET of FIR-RE (*Recife* Flight Information Region), valid from 12:00 UTC to 18:00 UTC, forecast the following weather conditions for the region:

- surface visibility of 3,000 m due to rain;
- isolated thunderstorms;

- isolated CB clouds (base at 3,000 ft and top above FL100);
- isolated TCU clouds (base at 2,500 ft and top above FL100);
- significant cloudiness at low altitudes (base at 800 ft. and top 1,400 ft, from 5 to 7 oktas (BKN); and
- cumulus-type cloudiness at low altitudes (base at 1,700 ft. and a top at 6,000 ft, from 3 to 4 oktas (SCT).

The SBSG 15:00 UTC METAR of 05 June 2022 contained information of wind from 250° at 4 kt, varying between 220° and 290°, visibility 9,000 m , rain in the vicinity, BKN at 1,500 ft, FEW towering cumulus clouds at 2,000 ft, BKN at 4,000 ft, temperature 25°C, dew point 24°C, and atmospheric pressure 1,014 Hectopascal.

METAR SBSG 051500Z 25004KT 220V290 9000 VCSH BKN015 FEW020TCU BKN040 25/24 Q1014=

In turn, the SBSG 15:17 UTC SPECI of 05 June 2022 had information of wind from 220° at 6 kt, varying between 130° and 250°, visibility of 9,000 m, rain in the vicinity, BKN at 9,000 ft, FEW towering cumulus clouds at 2,000 ft, BKN at 10,000 ft, temperature 25°C, dew point 23°C, and atmospheric pressure of 1,013 Hectopascal.

SPECI SBSG 22006KT 130V250 9000 VCSH BKN009 FEW020TCU BKN100 25/23 Q1013=

The 05 June 2022 15:00 UTC METAR of SBMS (destination aerodrome), had information of wind from 170° at 7 kt, visibility more than 10 km, BKN at 2,000 ft, scattered clouds at 9,000 ft, temperature 32°C, dew point 23°C, and atmospheric pressure of 1.013 Hectopascal.

SBMS 051500Z 17007KT 9999 BKN020 SCT090 32/23 Q1013=

Figure 5, extracted from the REDEMET, shows the Visible Satellite Image of the region of interest on 05 June 2022 at 16:40 UTC, close to the time of the accident.

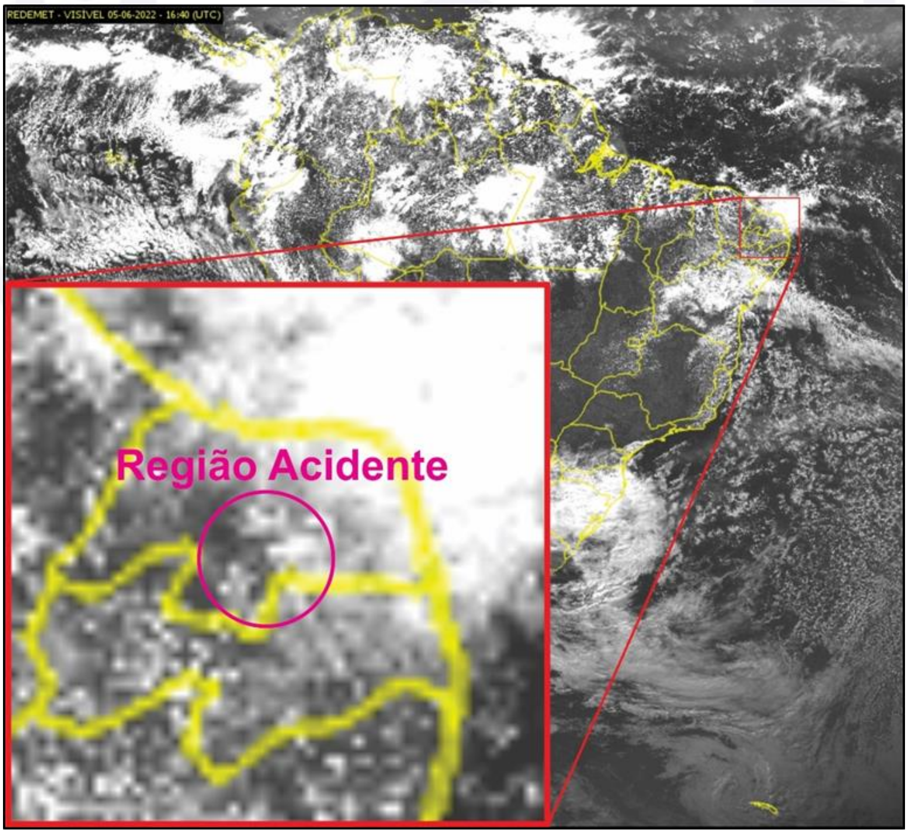

Figure 5 - Satellite Image of the region where the accident occurred.

The records of daily precipitation measured in meteorological data contained in the map of INMET meteorological stations showed a volume of 43.3 mm for the locality of *Caicó*, State of *Rio Grande do Norte*, located at a distance of approximately 46.5 NM away from the accident site.

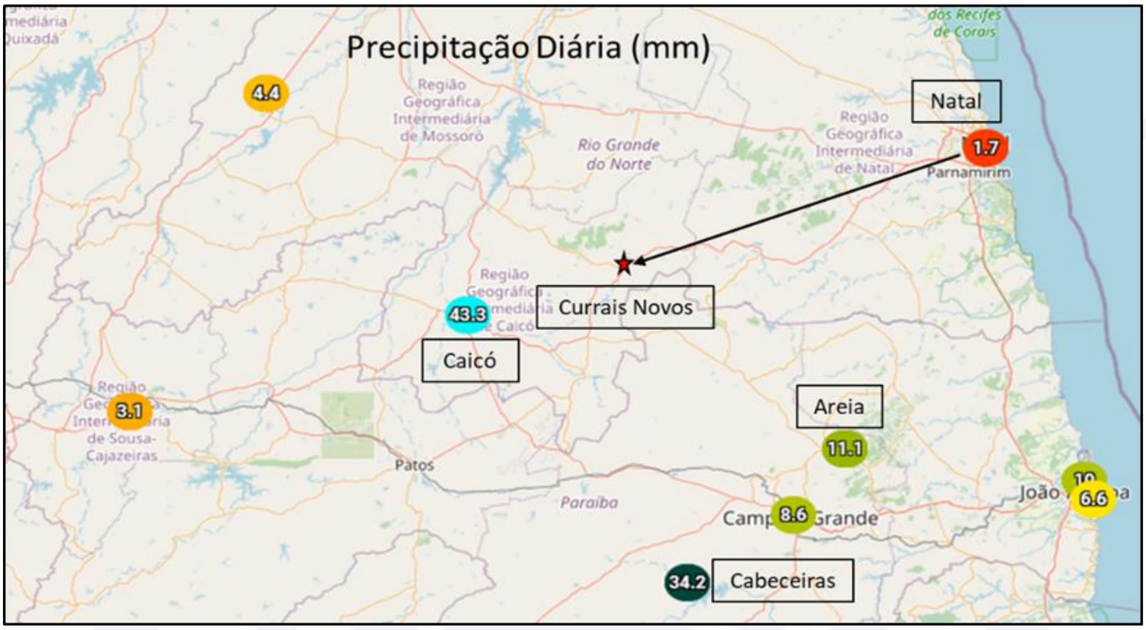

Figure 6 - Daily precipitation in millimeters on 05 June 2022. The arrow indicates the approximate trajectory of the aircraft. Source: INMET.

According to reports made by observers in the town of *Currais Novos*, located approximately 4 km away from the accident site, it was raining in the area.

A video, recorded moments before the accident, shows the helicopter in flight moments before the accident under the limited visibility conditions present in that region (Figure 7).


Figure 7 - Image of the PP-MCJ flying over the locality of Currais Novos.

Thus, given the meteorological conditions observed and forecast for the accident region, the Investigation Committee verified the existence of a relatively unstable atmospheric condition that featured rainy weather, with restricted visibility and variable cloudiness spread in various layers.

Therefore, one inferred that there were significant active meteorological phenomena, such as TCU clouds, rain showers, and low stratiform clouds over the region where the accident occurred.

1.8. Aids to navigation.

The aircraft operator had a WAC (World Aeronautical Chart), scale 1:1,000,000, issued by the Institute of Aeronautical Cartography (*ICA*), as well as a tablet and GPS navigation/positioning equipment, containing the delimitations of the transmission lines selected for inspection.

Next to the wreckage, one found the chart WAC 3018, 4th edition, from July 2004, in which the CHESF LTs were marked for purposes of flight planning. The Investigation Committee found, however, that the WAC was out of date and did not contain the mapping of the 230-kV LT that crossed with the 138-kV LT chosen for inspection.

Additionally, one verified that the chart did not have the other LT intersections marked in the planning of flights (Figure 8).

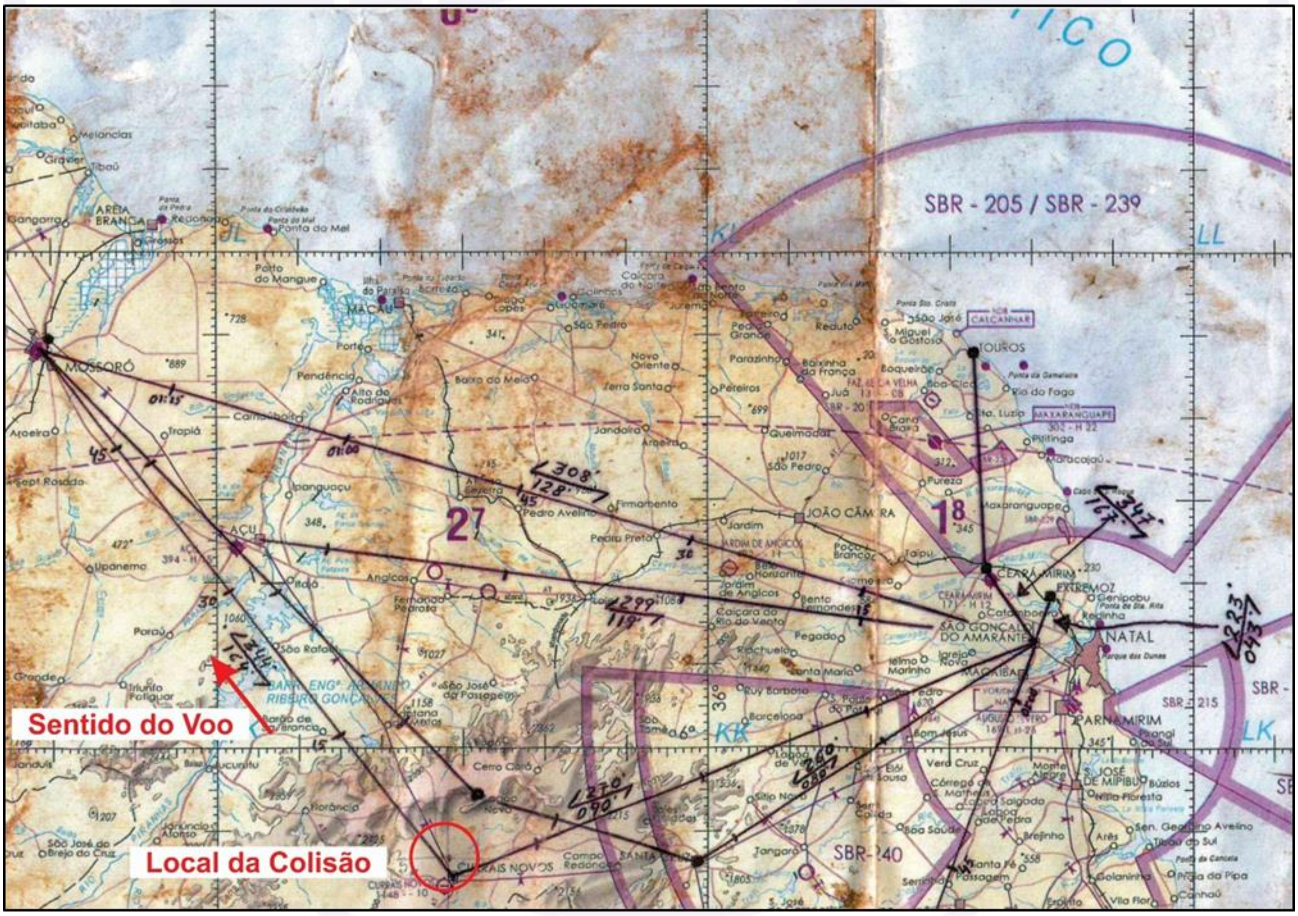

Figure 8 – Chart WAC 3018 - 4th Edition, 2004, found at the accident site.

At the time of the accident, the Chart WAC 3018, sixth edition, was the one in force (since 05 November 2020), with topographic data updated as of April 2020. In this publication, the 230-kV LT and its respective intersection with the 138-kV LT were mapped (Figure 9).

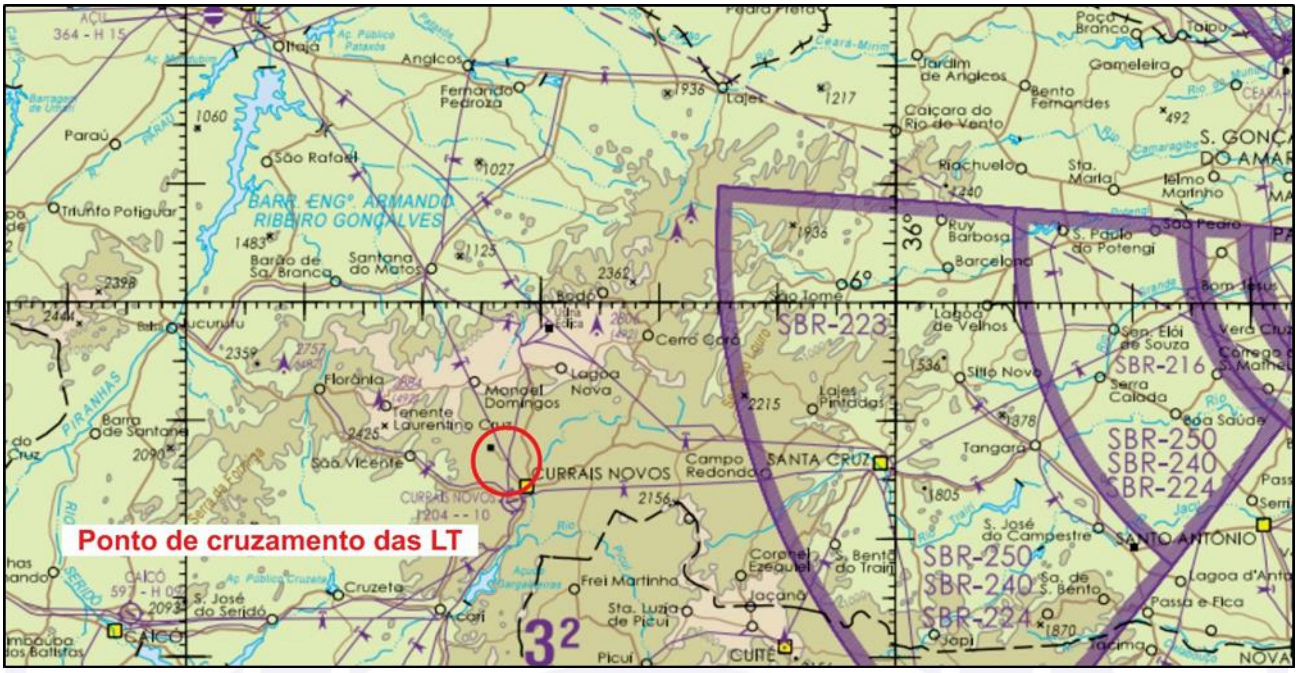

Figure 9 – Chart WAC 3018 - 6th Edition, 2020, in force on the date of the accident.

1.9. Communications.

NIL.

1.10. Aerodrome information.

The occurrence was outside aerodrome area.

1.11. Flight recorders.

Installation of recorders on the aircraft was not required.

The portable Garmim Aer 760GPS equipment used by the PIC at the time of the accident was sent to the Cenipa's LABDATA (Laboratory for the Readout and Analysis of Flight Recorder Data) for the reading of the memory card. However, extraction of data was not possible due to the degree of damage sustained by the referred equipment.

1.12. Wreckage and impact information.

The aircraft was equipped with an ELT (Emergency Locator Transmitter), PN 2619502-0027 and SN S1840501-01, with annual inspection valid until 10 March 2023. The ELT battery (PN LX1100457880, SN S1840510-01) was valid until 01 March 2023.

There were no records of the ELT's activation after the impact.

The PP-MCJ was flying parallel to the CHESF's 138-kV LT at a height of approximately 30 m, when it encountered the oblique intersection with the TAESA's 230-kV LT against which it collided.

Figures 10 and 11 show the intersection of the 138-kV LT with the 230-kV LT in the region close to the accident site.

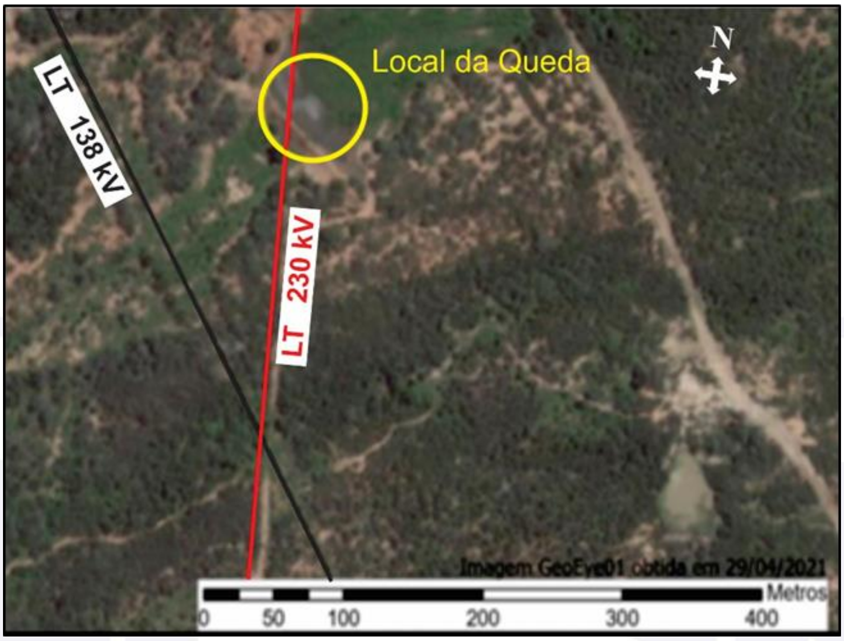

Figure 10 - Top view of the intersection of the 138-kV LT with the 230- kV LT.
In highlight, the dam where the PP-MCJ was found. Source: CHESF.

While the 138-kV LT had an average height of 30 m, and its electric cables were separated horizontally, the 230-kV LT cables had a height of approximately 40 m. (Figure 11).

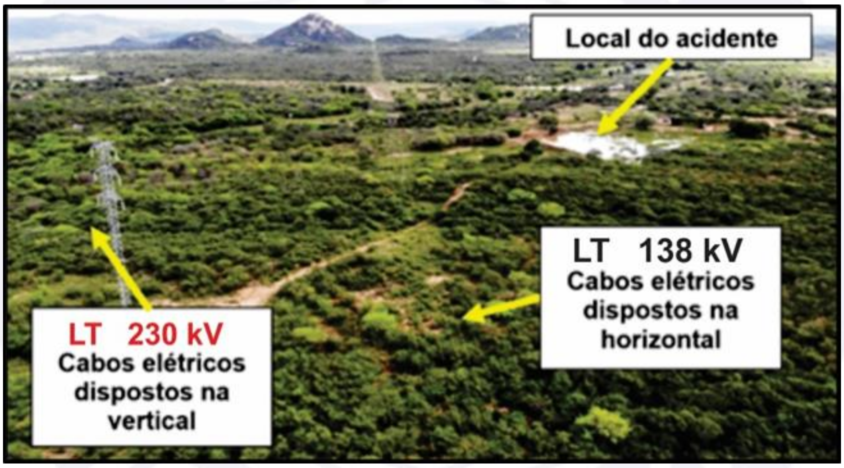

Figure 11 - Intersection of the 138-kV LT with the 230-kV LT.

The helicopter collided with a lightning-rod cable in the upper part of the 230-kV LT at a height of 41.66 meters. The transmission line cables were arranged vertically, as shown in the illustrative image in Figures 12 and 13.

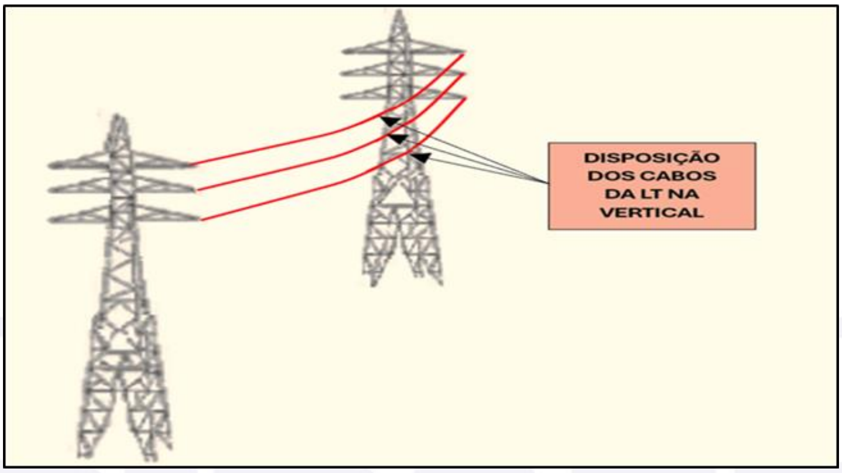

Figure 12 - Vertical arrangement of LT cables.

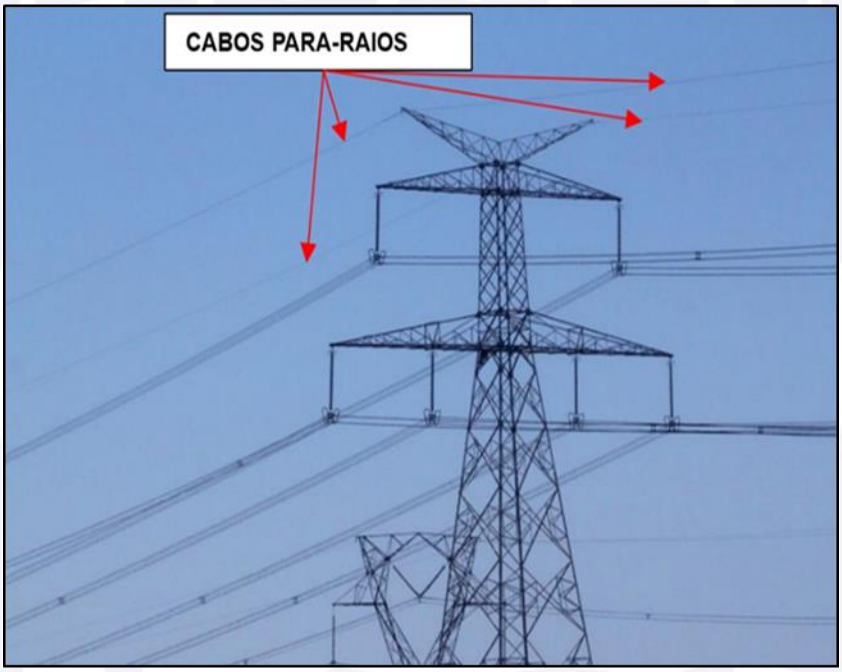

Figure 13 - Illustrative image of lightning-rod cables on the top of a LT.

The aircraft fell into a dam, at a distance of approximately 30 m from the point of collision, as shown in Figure 14.

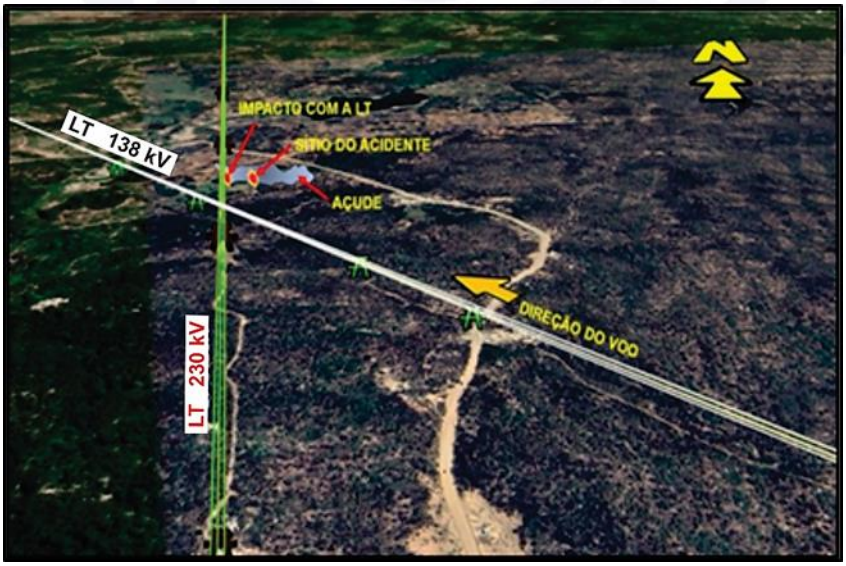

Figure 14 – Croquis of the accident.

Figure 15 shows an overview of the distances in the region where the accident occurred, illustrating the location of the helicopter collision against the 230-kV LT, and the respective elevations in relation to sea level.

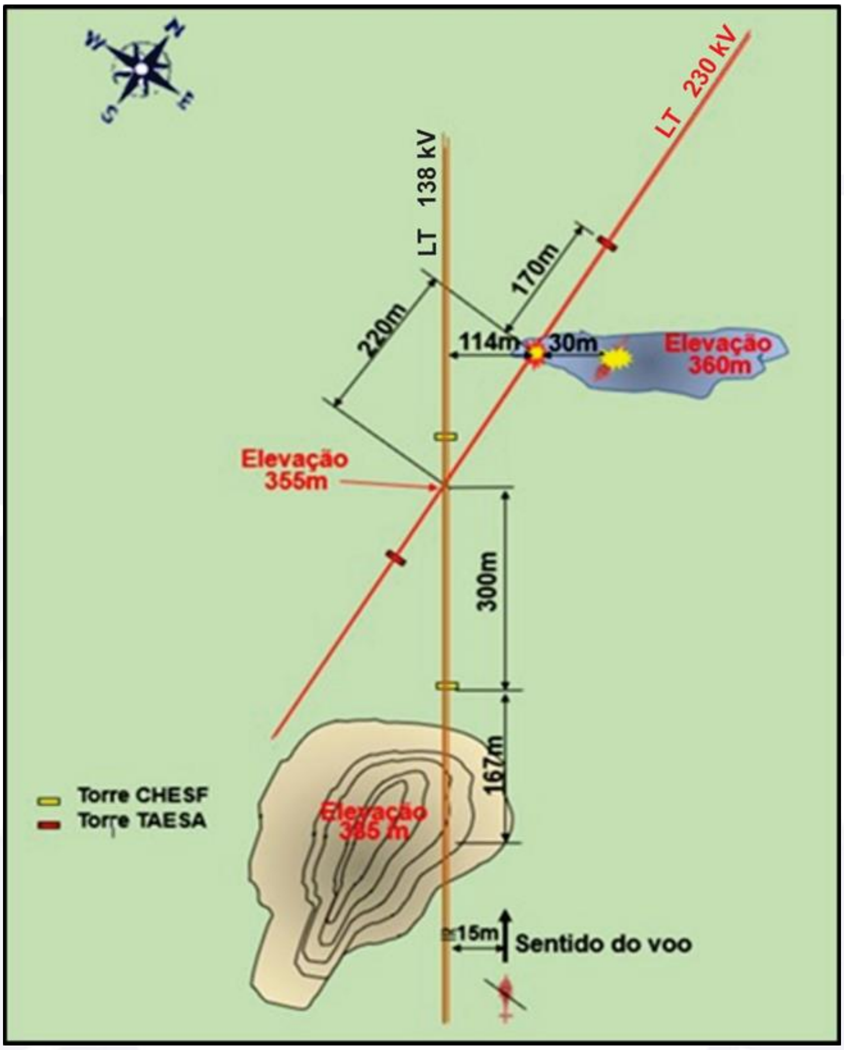

Figure 15 – Croquis with the dimensions of the LT and terrain elevations.

The wreckage was relatively concentrated, and was found partially submerged in the dam, and with the intermediate segment of the lightning rod attached to the aircraft (Figure 16).

Figure 16 - Aspect of the partially submerged wreckage.

One found a broken segment of the lightning rod entangled in the main rotor (Figure 17).

Figure 17 – Lightning-rod cable segment broken in two places (highlighted ends).

The main rotor blades showed damage and marks compatible with contact with the lightning-rod cable (Figure 18).

Figure 18 – Contact marks (grooves) between the lightning-rod cable and the leading edge of one of the main rotor blades.

Figure 19 shows the two blades of the main rotor, with the lightning-rod cable wrapped close to the root of one of them.

Figure 19 - View of the two main rotor blades.

The main rotor mast was sectioned near the main rotor hub, and showed signs of rubbing against the lightning-rod cable (Figure 20).

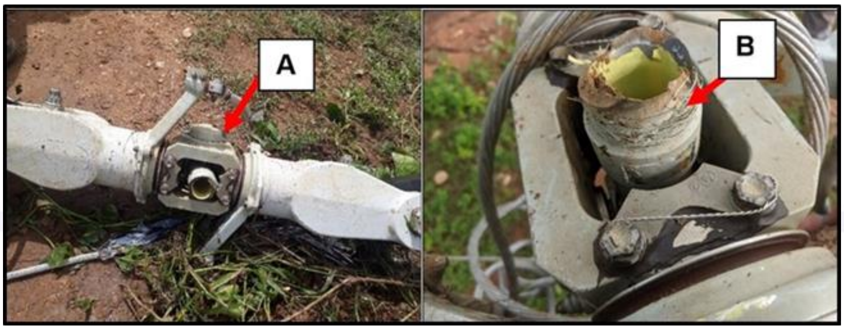

Figure 20 - Upper segment of the sectioned main-rotor mast (A) and detail of the rubbing marks against the lightning-rod cable (B).

Figures 21 and 22 show that the lower wire-cutter device had no traces of contact with the cable.

Figure 21 - Detail of the aircraft's lower wire-cutter with no traces of contact with the lightning-rod cable.

Figure 22 - Enlarged image of the aircraft's lower wire-cutter.

The helicopter's upper wire-cutter showed evidence of contact with the LT lightning-rod cable (Figure 23).

Figure 23 - Upper wire-cutter with evidence of contact with the lightning-rod cable.

The central deflector on the aircraft's windshield did not show any marks of contact with the lightning-rod cable (Figure 24).

Figure 24 - General view of the upper wire-cutter with the central deflector of the windshield.

The rear part of the central structure, as well as the attachment rods of the upper wire-cutter, showed signs of contact with the lightning-rod cable (Figure 25).

Figure 25 - General condition of the upper wire-cutter.

The left side of the rear skid cross tube showed signs of friction with the lightning-rod cable (Figure 26).

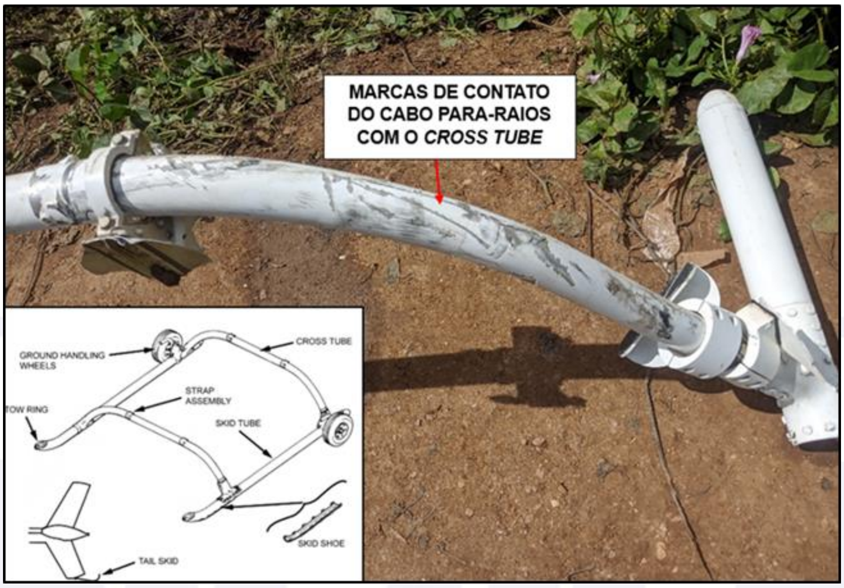

Figure 26 – Lightning-rod cable markings on the rear cross tube.

There was substantial damage to the left-hand horizontal stabilizer, with sectioning of the tail cone and tail rotor transmission shaft (Figure 27).

Figure 27 - Damage to the left-hand horizontal stabilizer, with sectioning of the tail boom and tail-rotor transmission shaft.

Figure 28 shows the damage to the tail rotor and the separation of the transmission box.

Figure 28 - View of the tail rotor and transmission box.

The aircraft's fuel tank sustained rupture (Figure 29).

Figure 29 – Aircraft debris, with the fuel tank in highlight.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

According to reports, the PIC had no history of health problems.

With regard to the PIC's working hours, no aspects were identified in conflict with those described in the RBAC-117 - "Requirements for Human Fatigue Risk Management", Amendment No. 00, dated 13 March 2019.

From the results of the exams and analyses carried out, the investigation did not detect any substances with a mass spectrum compatible with drugs of abuse and/or pharmaceuticals.

There was no evidence that issues of physiological nature might have affected the pilot's performance.

1.13.2. Ergonomic information.

On 20 November 2017, Flight Safety Australia published the article “Wire, the Invisible Enemy”.[1]

Based on an interview with expert Robert A. Feerst, the article highlights that wires may disappear from the eyes and become invisible. Even for a trained crew, several factors make wires invisible much of the time.

According to him, such factors include: atmospheric conditions; cockpit ergonomics; dirt or scratches on cockpit windows; viewing angle; sun position; visual illusions; pilot's scanning abilities and visual acuity; cockpit workload; and camouflaging effect of nearby vegetation.

A photo published on the *Piloto Policial* website corroborates the article, showing the effect of rain droplets on the windshield of a helicopter (Figure 30).

Figure 30 - Influence of rain droplets on the windshield of a helicopter, compromising the pilot's visibility. Source: *Piloto Policial* website.

The article also warns that older wires may be difficult to see due to color changes over time. Copper wires, for example, oxidize and acquire a greenish color that makes them camouflaged amid vegetation.

A wire that is perfectly visible from one direction may become invisible from the opposite. The exact location of specific wires may change throughout the day because of fluctuating ambient temperatures, which may cause wires to sag or tighten.

Even on a cloudless day, the blue of the sky can change to reveal, or hide, wires.

[1] Available on: https://www.flightsafetyaustralia.com/2017/11/wire-the-invisible-enemy/.

Long spans of wire lines may be blown by the wind, with displacements of tens of meters for wires crossing valleys.

Additionally, there are two types of illusions related to transmission lines, which deserve special attention:

- *High-wire illusion:* for two parallel wires at a distance of 200 m or more, the higher wire will appear further away, when it may not be; and
- *Phantom-line illusion:* a wire running parallel to others can become camouflaged.

According to Feerst, there are some principles one has to understand in the wire environment, and if one does not, one is operating on luck. “In environments where there are wires, it doesn't matter if you have 100 hours or 10,000 hours.” This being said, he lists three deadly assumptions:

> That you will see the wire in time. You can never count on it. It's a mentality you need to get out of your head.
>
> Never assume you and the pilot are seeing the same thing. Never assume the pilot has seen the wire.
>
> Never assume airspace is protected by marking and lighting. You just cannot count on that.

The article ends by concluding that:

> [...] if you do not have to fly in a wire environment, do not go there. If you do have to, seek training and regular retraining. Wire is an enemy that must be taken seriously.

1.13.3. Psychological aspects.

According to information provided by a family member, the PIC was a calm-tempered person, who was responsible and very diligent in relation to his work.

His relationship with his workmates and family members was reported to be harmonious with everyone.

His professional experience started in a company dealing with operations connected to offshore oil-and-gas exploration. Later, he joined CHESF, where he worked for around 33 years.

According to reports, in the two months preceding the accident, the pilot appeared to be well. However, he would show a certain level of irritation with some work issues, although he did not display any emotional alterations or changes in his behavioral patterns that might compromise the performance of his function.

Still according to reports, the PIC did not make use of controlled medications and, on the day of the accident, there were no records of any events outside the daily routine or even family-related problems.

It is worth noting that, by telephone, the PIC commented on the unfavorable weather conditions for the flight that resulted in the accident.

1.14. Fire.

There was no fire.

1.15. Survival aspects.

There were no survivors.

1.16. Tests and research.

With the aim of calculating the speed of the PP-MCJ from a video recorded by an observer, the Investigation Committee measured the aircraft's displacement in relation to its length (9.50 m) in the interval of five consecutive frames.

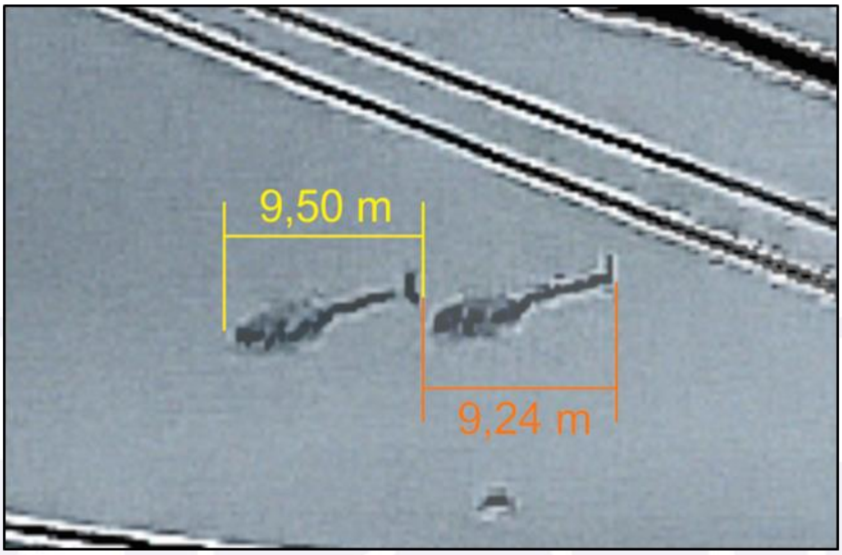

Figure 31 - Measurement of displacement (9.24 m) calculated in comparison with the length of the aircraft (9.50 m).

Considering the interval of five frames for the video, at a rate of 20 frames per second, one determined that the aircraft was moving 9.24 m in 5/20 s.

Therefore, the estimated aircraft speed recorded on video during the flight near the urban perimeter of *Currais Novos* was 71.84 kt (36.96 m/s).

1.17. Organizational and management information.

The PP-MCJ was an aircraft operated by CHESF, whose main activity was the generation, transmission, and sale of electrical energy. The company provided energy to a large part of the northeastern region of Brazil, being subject to the regulations of the National Electric Energy Agency (ANEEL).

According to information from *ELETROBRÁS* (as of 31 December 2022), the CHESF System consisted of the following transmission lines: twelve LTs of 69 kV, with a length of 195.54 km; eight LTs of 138 kV, with a length of 462.40 km; two-hundred-forty-three LTs of 230 kV, with a length of 15,678.35 km; and fifty-two LTs of 500 kV, with a length of 5,663.03 km.

In response to the consultation formulated by the Investigation Committee, CHESF informed that its transmission network had:

- 210 points of intersection, with voltage levels of 138 kV, 230 kV, and 500 kV;
- 26 points of intersection between CHESF and TAESA transmission lines; and
- 01 point of intersection along the 138-kV transmission line, which was being inspected at the time of the accident.

The flights for inspection of CHESF transmission lines took place under the responsibility of the *Paulo Afonso*'s Aviation Division (DOSPA), which had a fleet of two airplanes and four helicopters, whose maintenance was provided by an outsourced company.

At the time of the accident, DOSPA had a team of six pilots: four of them operated only helicopters, while the other two operated both fixed-wing aircraft and helicopters.

The DOSPA pilots would become aware of their participation in inspection flights by means of e-mail messages.

As CHESF aircraft were operated exclusively by the very company, such aircraft were not required to be in the Public Specialized Air Service (SAE) Registration Category, nor was it required for the said company to go through an SAE certification process. According to the ANAC's Resolution nº 659/2022, which regulated the exploration of air services by Brazilian companies, it would only be required for the company to be certified and the aircraft to be registered in the SAE category, in the case of provision of paid service.

It is also worth noting that, at the time of the incident, there were no specific regulations for this type of activity (transmission-line inspections).

ANAC's Resolution nº 293/2013 established the following definitions for the Registration Categories:

> Art. 60
>
> [...]
>
> II - Public Specialized Air Service (SAE): aircraft used to provide specialized air services, carried out by a Brazilian legal entity in exchange for fees, in which only people and materials related to the execution of the service have permission to be transported; and
>
> [...]
>
> VI - Private Air Services (TPP): aircraft used in services carried out without remuneration, for the benefit of the owners or operators, comprising recreational or sporting aerial activities, transport reserved to the owner or operator, specialized air services carried out for the exclusive benefit of the owner or operator, and without permission to perform any remunerated air services.

Therefore, the use of the TPP registration category aircraft, for one's own benefit, was in accordance with the regulations in force at the time.

In that scenario, since DOSPA was not a Civil Aviation Service Provider (PSAC) regulated by ANAC, there was no requirement for the implementation of a Safety Management System (SGSO/SMS), because the aircraft fleet operated under the rules of the RBAC-91 - "*General Operating Requirements for Civil Aircraft*".

Among other objectives, an approved SMS would have the one of establishing a Safety Policy for the identification of hazards and management of safety risks in the activities, as well as guarantee the application of the corrective actions necessary to maintain an acceptable level of performance in terms of safety.

<u>Application of the ABNT NBR 6535:2005</u>

At the time of the accident, the document in force was the ABNT NBR 6535:2005, which established the "*Minimum Criteria for Signalizing Overhead Electricity Transmission Lines*, *with a view to Aerial Inspection Safety*".

The aforementioned standard established the following minimum criteria for TL signage (emphasis added):

> 3. Requirements
>
> 3.1 Signage by painting line supports
>
> Painting is done in orange or red, according to the criteria defined in this section.
>
> <u>For the aircraft pilot, the orange color represents a warning to place himself in a safe position in accordance with the specific signage found, and the red color indicates an imminent obstacle. All lines are signposted for either direction of the aircraft.</u>
>
> 3.1.1 Intersection of transmission lines
>
> <u>At the intersection of transmission lines, the lower line supports must be painted in accordance with the following criteria:</u>
>
> a) at least two supports adjacent to the intersection are painted;
>
> b) the segment of the transmission line to be signalized before the intersection is numerically equal to eight times the difference in the heights of the highest cables of the two transmission lines (lightning rods or conductors) at the point of intersection,

for the condition in which this difference is maximum. The support immediately beyond the calculated distance, from the point of intersection, must also be painted;

c) at least the upper half of the supports is painted, on the external surface facing the direction of approach of the aircraft;

d) <u>the support adjacent to the intersection is painted red, and the others are painted orange, according to the color standards in table A.1</u>;

e) the climbing devices on the supports are not painted;

f) when the number of supports between consecutive intersections is equal to or less than three, all internal supports of the intersections are painted in red.

[...]

3.3 Sphere signage

<u>The spheres for the signage specified in this section must be orange or red, in accordance with the color standard in table A.1, with a diameter of 600 mm.</u>

3.3.1 At the intersection of transmission lines, lightning rod cables or conductors that are taller on the upper line are signalized by at least three spheres spaced at a maximum of 30 m apart.

3.3.1.1 In the case of a transmission line with a taller lightning rod or conductor, the intermediate sphere is placed at the point of intersection with the axis of the lower line.

NOTE See application example in figure B.11.

3.3.1.2 In the case of transmission lines with two lightning-rod cables or more than one conductor of greater height, the spheres are distributed, preferably, alternately on the lightning-rod cables or on the lateral conductor cables, with the intermediate one placed at the point of intersection with the axis of the lower transmission line.

NOTE See application example in figure B.12.

3.3.1.3 The highest lightning-rod cable or conductor in each span adjacent to the support or point of intersection is signalized by a sphere placed at a horizontal distance of 15 m from the cable furthest from the axis of the transmission line.

NOTE See application example in figure B.2.

3.3.2 At exiting branches or derivations or line terminals, the procedures in 3.3.2.1 and 3.3.2.2 must be adopted.

3.3.2.1 The highest lightning-rod cable or conductor in each span adjacent to the support or branching point is signalized by a sphere placed at a horizontal distance of approximately 15 m from the cable furthest from the line axis.

NOTE See application example in figure B.4.

3.3.2.2 In the case of transmission lines with two lightning-rod cables or more than one conductor cable of greater height, the lightning-rod cables or the lateral conductor cables are signalized.

The Investigation Committee verified that, in the vicinity of the intersection of the transmission lines where the accident occurred, the 138-kV LT towers were not signalized by painting in accordance with the criteria of the ABNT NBR 6535:2005 (Figure 32).

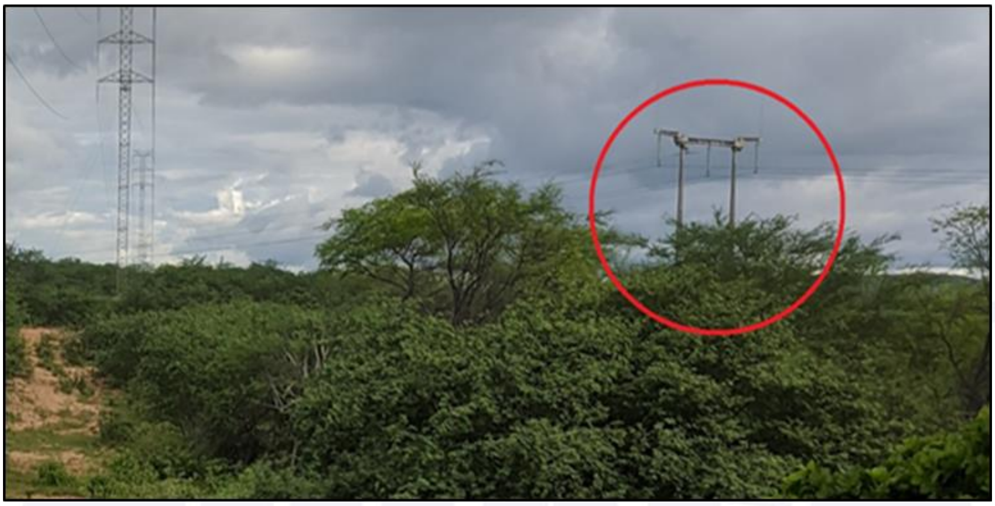

Figure 32 – Vicinity of the intersection of the 138-kV with the 230-kV transmission lines, highlighting the lack of signage on the tower (support) of the 138-kV LT.

The 230-kV LT cables had orange warning spheres (Figure 33).

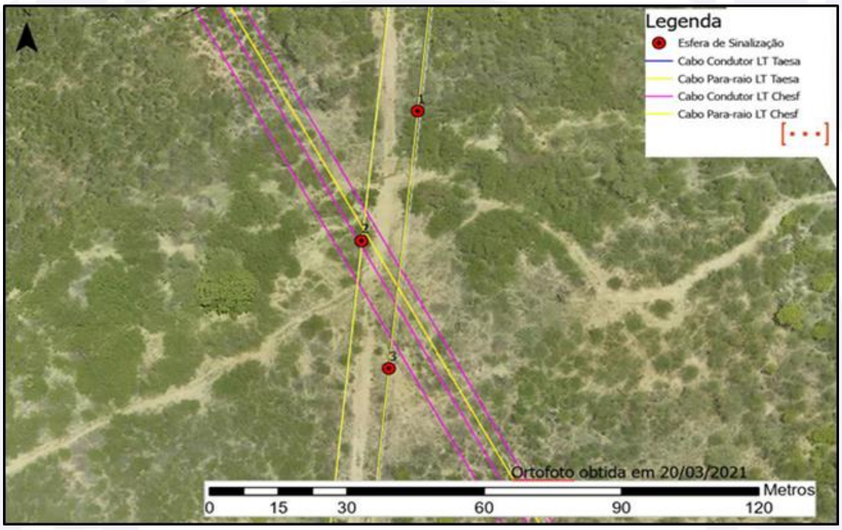

Figure 33 - Location of the warning spheres existing before the accident.
Source: CHESF.

Figure 34 indicates the location of the warning spheres of the electrical cables 1, 2, and 3, respectively, of the 230-kV LT.

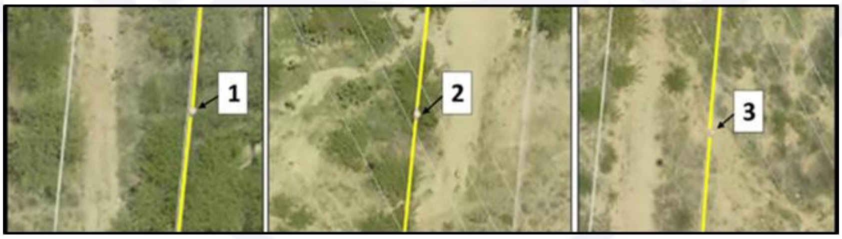

Figure 34 - Identification of the warning spheres of the electrical cables 1, 2, and 3, respectively, of the 230-kV LT.

At the collision with the transmission line, the 230-kV TL warning sphere number 1 fell to the ground due to breakage of the lightning-rod cable (Figure 35).

Figure 35 – Aircraft warning sphere nº 1 on the ground,
due to breakage of the lightning-rod cable of the 230-kV LT.

In turn, the warning sphere nº 2 remained in its position at the intersection (Figure 36).

Figure 36 - Warning sphere nº 2 of the 230-kV LT

With respect to the painting of the unmarked towers close to the intersection, the Investigation Committee was informed by a DOSPA representative that, on account of an agreement signed by the companies, the operator of the 230-kV LT would be responsible for signalizing (painting) the towers (supports) of the 138-kV LT existing on the location, based on the criteria of the ABNT NBR 6535:2005.

Relatively to compliance with the agreement in question, the fact that the CHESF's 138-kV LT had been installed before the TAESA's 230-kV LT was taken into consideration.

Still in relation to the signage, one observed that, approximately six months before the date of the accident, there had been an exchange of messages internally to DOSPA on identified non-conformities (in light of the ABNT NBR 6535:2005), such as, painted towers barely visible or without paintings, intersections of transmission lines without signage, in addition to towers and intersections not duly entered on the tablet and portable GPS devices used by the pilots.

1.18. Operational information.

The aircraft was within the weight and balance limits specified by the manufacturer.

On the day of the accident (05 June 2022), the PP-MCJ operated from SBSG, fulfilling the schedule of aerial inspections of transmission lines, comprising the following segments:

- morning period: *Natal* / *Ceará-Mirim* / *João Câmara* / *Extremoz* / *Touros*; and
- afternoon period: *Natal* / *Paraíso* / *Santa Cruz* / *Currais Novos* / *Santana do Matos* / *Açu* / *Mossoró*.

The aerial inspection scheduled for the morning period was completed.

The flight plan for the segment in which the accident occurred had the flight identified as type "G" (general aviation), with takeoff scheduled for 15:30 UTC, destined for SBMS under Visual Flight Rules.

The estimated duration of the flight was 2 hours and 30 minutes, and the declared fuel endurance was 3 hours and 30 minutes. As an additional piece of information (RMK), the flight plan records stated that the flight was intended for inspection of transmission lines at a height of 500 ft. AGL.

The flight was conducted in Class G airspace (*outside controlled airspace*).

Relatively to VFR flights, the Command of Aeronautics' Instruction (ICA) 100-12 - "Rules of the Air", in force on the date of the accident, established that:

> 5.2 PILOT'S RESPONSIBILITY
>
> It is the responsibility of the pilot-in-command of an aircraft flying VFR to provide his own separation from obstacles and other aircraft through the use of vision, except in Class B airspace, in which separation between aircraft is the responsibility of ATC, without prejudice to the provisions prescribed in 4.2.1.

The accident occurred in the afternoon period, at the point of the oblique intersection of the 138-kV LT with the 230-kV LT (Figure 37).

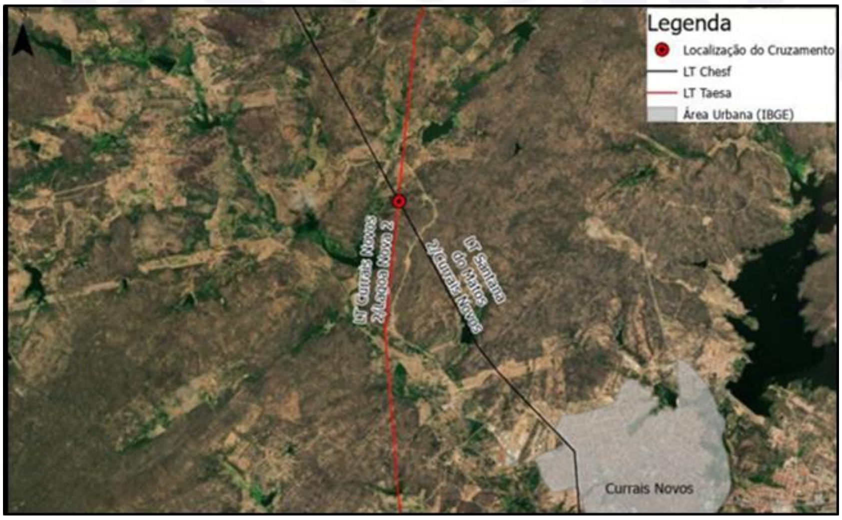

Figure 37 - Geographic location of the intersection of the 138-kV LT with the 230-kV LT, having the town of *Currais Novos* as a reference.

The aircraft fleet operated by DOSPA did not have on-board equipment with audible and/or visual warnings to alert pilots on the proximity of obstacles, such as transmission lines.

In order to deviate from the existing intersections of the various transmission lines, in addition to their permanent concern related to the visual detection of such obstacles, pilots had to observe the signage of the transmission lines (ABNT NBR 6535:2005), warning them of the proximity of those intersections.

The Investigation Committee noted that the planning of flights conducted by DOSPA did not usually include face-to-face briefings. Presence briefings would be important occasions for dealing with flight specificities, notably those relating to the identification of hazards, as well as adoption of risk mitigation procedures.

Instead, one found that the briefings were effected via e-mail messages addressed to the pilots, through which assessments and suggestions could be presented. Such briefings contained details of the missions, such as dates, routes, and scheduled transmission-line inspectors. However, there were no considerations on the safety of operations.

As for the *debriefings*, these were not held, except in some informal and exceptional situations, such as those in which poor signage of LT towers was reported, or when there was a need to repeat the aerial inspection of a certain LT.

There were no formal tools that could be used by pilots to inform other sectors of the CHESF Company on the identification of hazards for the air operations. In specific cases of poor TL signage, the pilots informally asked the inspectors to report the observed non-conformities to the various sectors of the company.

In that scenario, there were no policies in place to foster monitoring on the part of DOSPA concerning the adoption of pertinent measures.

The operator did not have standard operating procedures which, among other aspects, could established the use of a callout to alert, for example, on the proximity of obstacles and intersections of transmission lines, weather minimums, vertical and horizontal distances from transmission lines, or other conditions that could impair air operations on account of safety reasons.

DOSPA’s pilots had agreed that, during LT inspection flights in model 206 helicopters, a torque between 72% and 75% (engine operating speed) would be used, implying average speeds between 85 kt. and 90 kt.

The speeds could be changed, depending on the requests of the inspectors on board, or the pilots' assessment in relation to the required fuel endurance of the aircraft to reach the destination and/or alternate aerodromes.

According to a report from the operator's pilots, the PIC used to adopt an inspection-flight profile which would lead him to remain approximately 5 m above, using the skid (landing gear) as a reference, and 15 m laterally away from the inspected cables, using the edge of the main rotor as a reference (Figure 38).

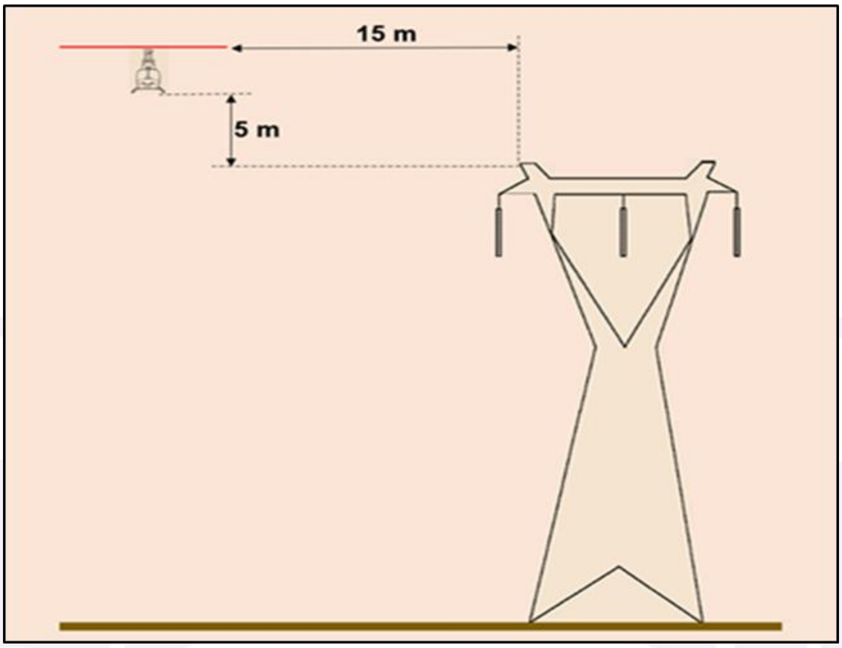

Figure 38 - Flight profile adopted by the PIC in relation to the inspected LT.

CHESF pilots reported that, during the inspection of the 138-kV LT, in the segment where the accident occurred, the PP-MCJ would probably be at a speed of approximately 80 kt. and maintaining a height of around 35 m AGL. They added that the PIC of the accident flight recommended that other pilots stay away from the LT when meteorological phenomena and/or rain droplets were present during the flight.

1.19. Additional information.

Command of Aeronautic's Instruction (ICA) 100-4, of 21 July 2021

With respect to the operation of helicopters, the ICA 100-4/2021, "Special Air Traffic Rules and Procedures for Helicopters", established the following:

> 3 VISUAL FLIGHT RULES
>
> 3.1 GENERAL CRITERIA
>
> [...]
>
> 3.1.3 Outside controlled airspace, below an altitude of 3,000 ft. or a height of 1,000 ft. above the terrain, whichever is greater, the VFR flight of a helicopter will only take place when, simultaneously and continuously, the following conditions can be met:
>
> a) to maintain flight visibility conditions equal to, or greater than, 1,000 m, provided that the flight speed is sufficient to see and avoid traffic or any obstacle with sufficient time to prevent a collision; and
>
> b) to stay away from clouds and to maintain reference with ground or water.
>
> 3.2 MINIMUM HEIGHTS FOR VFR FLIGHTS
>
> 3.2.1 Except for landing and takeoff operations, or when authorized by the DECEA's Regional Organization with jurisdiction over the area in which the operation is intended, the VFR flight of helicopters will not take place over cities, towns, inhabited places, or over a group of people outdoors, at a height of less than 500 ft above the highest obstacle within a radius of 600 m around the aircraft.
>
> 3.2.2 In places not mentioned in 3.2.1, the flight will not take place at a height lower than the one allowing, in the event of an emergency, to land safely and without danger to people or properties on the surface.
>
> NOTE: The mentioned height must be of at least 200 ft.

Supplementary Instruction (*IS*) nº 00-010, of 05 June 2020

The *IS* dealing with CRM (Crew Resource Management) established criteria and procedures for CRM implementation and maintenance, as follows:

5.1 INITIAL Provisions

5.1.1 The CRM training is based on the premise that a high degree of technical proficiency is essential for air operations to be safe and efficient. Mastery of CRM concepts does not compensate for a lack of proficiency. Likewise, high proficiency does not guarantee safe operations in the absence of effective crew coordination.

5.1.2 The mastering of concepts requires continuous effort acting at different levels: knowledge, skills, and attitudes.

5.1.3 The training should focus on teamwork, and not simply treat those involved as a set of technically competent individuals. It should provide team-members with opportunities to practice their skills together, performing the roles normally assigned to them on a day-to-day basis.

5.1.4 The training must provide each team-member with the opportunity to improve the use of individual characteristics to promote team effectiveness. To achieve this, the greater each person's awareness of their behavioral repertoire, both in normal situations and in contingencies, the greater the understanding of the weak points that require changes to improve the results of the team's work.

5.1.5 The training must lead team-members to remind that attitudes during normal and routine circumstances have consequences for the team's behavior in times of high workload or stress. Similar situations experienced in training will increase the probability of coping with the stressful situation competently.

5.1.6 The effectiveness of CRM training must be based on the analysis of standard operating procedures (SOP). The more comprehensive, clear, logically structured, and updated they are, the better for team performance.

5.1.7 The CRM Training is defined by the following characteristics:

a) Application of human-factors' principles to improve team performance.

b) Inclusion of personnel involved with the type of aerial operation, which must be listed in the CRM training program.

c) Insertion of elements of CRM training in all training contained in the Operational Training Program, so that the CRM philosophy becomes part of the organization's culture.

d) Focus on people's attitudes and behaviors as team-members, and the impact they have on safety.

e) Provision of opportunities for each team member to analyze their own attitudes and promote appropriate changes, with the aim of optimizing their ability to work as a team and make timely decisions.

f) Customization in light of one's target audience, in line with the training needs to comply with the company's human factors/CRM policy, considering the strategic, tactical, and operational levels.

5.1.8 The application of CRM in the 'corporate' modality means adding other segments of the organization that can impact the operation, generating latent failures that make the system vulnerable, without, however, failing to consider the training needs of operational staff. The program of CRM training must be constantly evaluated, as guided in section 5.5 - Evaluation and Validation of CRM Programs, of the *IS* mentioned above.

In May 2022, CHESF pilots underwent CRM training, which included the following curriculum:

- basic conceptualization of Human Factors (HF);
- definitions on Human Factors and Ergonomics;
- study models: Reason and SHELL;

- training in team resource management;
- communication and decision-making processes;
- individual stress factors and their effects on performance;
- concepts of errors and threats;
- training and maintenance of teams;
- automation;
- case studies;
- situational awareness;
- group techniques;
- administrative activities;
- evaluation activities;
- evaluation of training;
- activities of integration;
- interpersonal dynamics;

The transmission-line inspectors did not participate in the training.

Likewise, in May 2022, DOSPA held an SGSO (SMS) course for its pilots.

Both events were not mandatory according to the existing provisions of the RBAC-91, under which the PP-MCJ operated.

Furnas' Field Technical Manual

By way of illustration, *Furnas Centrais Elétricas S.A*., a subsidiary of Eletrobras that also operated in the generation, transmission, and commercialization of electrical energy, prepared, in July 1995, a "Field Technical Manual" dealing with "Aerial Inspection of Transmission Lines using Helicopters".

The manual was intended to provide helicopter pilots and line inspectors of the referred company with a few parameters for the development of the LT aerial inspection activity, and contained a description of the standards and procedures that should be observed, both by helicopter pilots and transmission line inspectors during the execution of aerial inspection services.

To such purpose, an approach was adopted on various technical and safety-related factors involved in the activity.

Among the topics covered, the responsibility of the helicopter pilot during operations was defined, as per item 5 below:

> 5. Helicopter Pilot's Responsibility
>
> The pilot is primarily responsible for the safety of the aircraft. He must keep him/herself informed of the weather conditions along routes of flight, and has ultimate authority to cancel any flight due to mechanical problems, weather conditions, and other safety-related conditions.

Relatively to the safety of inspection flights, the following aspects were highlighted:

> 7.2.1. Before the start of every mission, both the pilot and the LT inspector must be aware of the flight schedule to be accomplished, the refueling points, the overnight locations, etc.
>
> 7.2.2. The LT inspector must also be aware of the topographical characteristics of the region of the flight, the weather conditions, etc.

7.2.3. Whenever possible, flying with the sun shining directly ahead in the direction of inspection should be avoided, as the pilot's visibility is significantly impaired.

7.2.4. To ensure flight safety, the transmission line being inspected must be identified and signalized, in order to accommodate both possible directions for the inspection.

7.2.5. The height of the aircraft in relation to the ground (distance *h*, measured in meters) should be approximately the height of the tower. The lateral distance of the helicopter relatively to the conductor cables (distance *d*), should be approximately 15.0 m.

7.2.6. If there are three or more parallel lines, those in the center must be inspected, with the helicopter being placed to the left or right of the lines, depending on the type of helicopter used (controls on the right or left side), so that there is no visual interference between the inspector and the line being inspected.

7.2.7. If the LT crosses a gorge, the helicopter must remain at the height of the cables.

Furthermore, the manual limited the average speed of the helicopter on an inspection flight to 30 kt. (55 km/h).

<u>Safety Standards for Patrols</u>

The *Comite de Construcción y Patrullaje de Sistemas de Servicio Publico de la Asociación Internacional de Helicópteros* (HAI), through Utilities / Aviation Specialists Inc. published, in 1995, the compendium "*Evitando El Impacto Con Los Cabos*", which encompassed the *Norms de Seguridad para el Patrullaje*, with the aim of providing information for those involved with the construction and maintenance of electrical energy transmission lines.[2]

It is important to clarify that the recommendations contained in the publication had an advisory nature.

Among the subjects presented, special mention should be made of the *"Procedimientos para Patrullaje y Sistemas de Distribución Eléctrica*" (Procedures for Inspection of Electric Power Systems), listed below:

- get familiarized with the electrical distribution system. This will allow the pilot to anticipate where the cables are, rather than relying exclusively on visual contact with them. Distribution systems are not static: they are dynamic and always changing;
- normally, the higher voltage network has to be installed above the lower voltage wires. It's best to know what voltage to expect in the area you're flying in, so one knows what to find above or below the lines;
- when inspecting a system you are not familiar with:

. start with the higher voltage system. This will allow one to observe the crossings of the cables from the higher to the lower point;

. in order to improve inspection quality and safety, make sure the pilot or line inspector is familiar with the system they will inspect;

. the pilot should focus on identifying the transmission line intersections and other sensitive issues, allowing the inspector to have the best picture to ensure line inspection. The inspector must focus on developing good practices and observation techniques. The pilot and inspector must work together as a team;

. maintain low speed, as this increases the possibility of sighting the cables in time. An early visual detection is much more effective than slowing down;

[2] FEERST Robert A. Evitando El Impacto Con Los Cabos, Utilities/Aviation Specialists Inc.,1995, Traducción por Asociación Latinoamericana de Aeronáutica (ALA)

. the lower the voltage on the lines to be inspected, the greater skill will be required. The complexity of low voltage systems increases the stress level of the inspection job;

. ask the power company for information and circuit maps of new transmission lines and projects under construction;

. work together with the energy company in preparing transmission line intersection programs; and

. do not assume navigation charts are up to date in relation to intersections of transmission lines.

Among the proposed recommendations to be observed before the flight, the following ones are worth to be highlighted:

- the pilot and inspectors should hold a meeting to discuss the inspection environment, the weather, the fuel requirements, the route, any known and/or recent obstacles, and noise sensitive areas;
- the pilot and inspectors must work as a team. Before each inspection, one should evaluate the team's experience. One should make adjustments to ensure maximum safety;
- the pilot must have qualification and be familiar with the helicopter; and the inspector must be familiar with the system or with the transmission network;
- the team must have extensive knowledge of each member's primary functions. It is important that the pilot does not get too involved with the inspector's duties;
- one should review inspection procedures, including standardized callouts for normal and emergency conditions;
- for greater inspection efficiency, the pilot has to identify the angle, speed and distance of cables and structures, taking into account the inspector's needs;
- one must always keep windows clean;
- one should comply with the plan that was conceived;
- the pilot must avoid operating the helicopter close to its maximum weight; and
- one has to consider the use of personal protective and survival equipment.

In relation to the inspection flight itself, the compendium highlighted that the following precautions should be taken:

- paying attention to the possibility of the presence of new transmission networks, supports, and towers. The construction of new roads may indicate changes in the transmission system;
- not all intersections will be identified. Be alert for other signs of lines “above” and “below” at points of intersection;
- flights over cables must be carried out above structures (towers) of higher voltage lines. This will generally ensure that the highest lines are flown over;
- one must ensure that intersections of transmission lines are mandatorily mentioned in flight;
- keeping the helicopter skids above the highest cable of the inspected structures. If for any reason it is necessary to operate at heights lower than the highest cable, speed must be reduced to allow sufficient reaction time for the avoidance of hidden obstacles;

- the pilot's main function is to fly the aircraft. He/she has to avoid performing the inspector's duties. Working as a team and establishing a CRM concept are activities that must be continually motivated;
- as new obstacles are encountered during the inspection, take notes of their location on the navigation charts, maps, or GPS for a review after the flight or for future reference;
- flights in the direction of the sun, at dusk or at dawn, may reduce one's ability to sight cables due to reflection or glare. This must be taken into consideration, especially when inspecting areas and systems with which the pilot is unfamiliar;
- when terrain conditions permit, inspection flights should be considered on the windward side of the cables. The pilot should assess wind speed and direction, trying to fly against the wind;
- avoid judging the distance of cables, especially braided cables, based solely on visual references. The potential for optical illusions and poor judgment is high; and
- when the inspection requires close observation of the cables, operations in hover or at low speed must be considered.

Post-flight procedures:

- after every inspection flight, the crew must hold a debriefing to analyze the flight performed and catalog new information and/or obstacles that may be important for future flights.

EASA Community Network - What can you do to reduce the risk of cable collisions?[3]

On 31 March 2022, EASA (European Union Aviation Safety Agency) published an article that addressed the subject of Cable Collisions.

According to the text, *electrical wires and other cables are statistically one of the most significant hazards for helicopters, especially for Low Altitude Operations (LALT) and may result in fatal accidents*. The article presents the EASA animation "*Helicopter Wire Strike Avoidance - Wires in the Helicopter Environment*" and develops good practices introduced in the video that can help one avoid wire strikes.

The article contained some recommendations for the various phases of a helicopter flight in such condition:

- *Planning and preparation:*

. *Undergo a wire-strike safety-training program which implements wire avoidance flying techniques and procedures in flight, including understanding of hazards, mission preparation, and Crew Resource Management (CRM);*

. *Understand the risk of wire strikes and take the necessary precautions, especially when flying at low altitude;*

. *Prepare your flight thoroughly and review any known cable installations on the planned flight path. Every year, thousands of new electrical and communication towers and antennas and hundreds or thousands of kilometers of wires are added - the situation can change from one day to another;*

[3] Available on: https://www.easa.europa.eu/community/topics/cable-collisions

. Always download the latest version of maps locating wires and other hazards, such as natural and artificial obstacles, including wind turbines, in your flight area. Familiarize yourself with the terrain, navigation charts, and obstacles;

. Use, if possible, an aircraft equipped with wire-detection and avoidance equipment, and wire cutting technologies;

. Using airborne technology for the obtainment of maximum benefit requires dedicated training.

. Note that pilots often turn off cable or terrain audio warnings as these may disturb attention during highly critical maneuvers and exceed one's mental processing capacity. Detection systems are ineffective when audio warnings are turned off!

. If you are used to operating a helicopter equipped with detection systems, the risk can increase when switching to a non-equipped helicopter because you are used to, but won't receive audio warnings.

- During the flight:

. Do not fly at low altitude unless necessary for the operation;

. Around 40% of the pilots who hit wires despite knowing knew they were there couldn't see them. Visibility becomes a huge issue when looking at the wires from above. Even when wires are visible from the ground, they are not consistently visible to pilots in the air;

. At a typical flight speed, most wires are hard to see. Maintain situational awareness during the whole flight, and ensure there is sufficient clearance from any obstacle on either side of the flight path and at all heights, especially in mountainous or hilly environments. Stay focused on the flight and avoid distractions;

. Invite everyone on board to look actively for cables, support structures, terrain, obstacles, and traffic, especially when the mission requires flying at low altitude;

. It is recommended to make a higher level reconnaissance before descending below 500 ft. and entering a potentially dangerous wire environment;

. Pay maximum attention to the flight path ahead. Make a slow, wide sweep over a 70º wide field starting from the center of sight;

. Look for wires and indicators which may reveal the presence of wires, such as towers, poles, and pathways cut out in trees. Expect wires around roads and buildings, and towers on hills and hilltops;

. In Specialized Air Services, Medical Services, and other critical missions (power line inspections) performed at low altitude, external influences such as changing wind direction or gusts can be highly dangerous, especially in mountainous areas. Also be careful with weather conditions and reduced visibility; and

. Flight preparation and anticipation are of paramount importance. Mission training, CRM, and experience gathering are essential aspects for the safe conduction of specialized missions.

The article concludes by stating that even the latest version of maps with obstacle locations is not a guarantee that all of them have been properly identified.

In addition, the article reminds that all types of wires must be taken into account, such as transmission line cables, support cables, electrical and communication cables, mobile tree cables, cable cars, etc. Thin cables are particularly difficult to sight and may be hidden by trees and other natural or artificial obstacles.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

The purpose of the flight was to inspect a CHESF 138-kV transmission line in the segment between *Currais Novos* and *Mossoró* in the State of *Rio Grande do Norte*. The PIC filed a VFR plan for a flight in uncontrolled airspace, originating in SBSG and landing in SBMS, at an altitude of 500 ft AGL.

During the inspection flight, the aircraft collided with a TAESA's 230-kV transmission line near the town of *Currais Novos*. Subsequently, the aircraft fell into a dam, where it rested partially submerged.

The PIC had qualification and experience for the type of flight, and held a valid Aeronautical Medical Certificate.

The records of the aircraft's airframe and engine logbooks were up to date. The CVA (Airworthiness-Verification Certificate) of the aircraft was valid. There was no evidence of failure or malfunction of aircraft systems and/or components that might have affected its performance or control in flight.

The aircraft, registration marks PP-MCJ, was registered in the TPP Registration Category, and operated under the rules of the RBAC-91.

On account of the dynamics of the collision, the WSPS equipping the helicopter was not sufficient to minimize the consequences of the impact against the transmission line cable.

The presence of adverse weather conditions during the operation period had caused the cancellation of the initial flight of the schedule on the morning of 31 May 2022, leading the aircraft to return to *Paulo Afonso*, State of *Bahia*.

On the day of the accident, the 18:00 UTC SIGWX, with weather information from the ground surface to FL250, forecast cloudy skies with the presence of Cumulus (CU) and Stratocumulus (SC) clouds with base at 1,700 ft and top at 6,000 ft; Towering Cumulus (TCU) clouds with base at 2,500 ft.; and showers of rain.

In turn, the 05 June 2022 FIR-RE GAMET, valid from 12:00 UTC to 18:00 UTC, forecast the following meteorological conditions for the region: surface visibility of 3,000 m due to rain; isolated thunderstorms and CB, base at 3,000 ft and top above FL100; isolated TCU, base at 2,500 ft., and top above FL100; significant cloudiness at low altitude, base at 800 ft and top at 1,400 ft., broken and scattered Cumulus clouds with base at 1,700 ft and top at 6,000 ft.

Thus, in relation to the weather conditions forecast and observed in the area of the accident, one found that there was a relatively unstable atmospheric condition, with restricted visibility, which provided rainy weather, with variable multilayer cloudiness, and prevailing winds from the South. .

According to the history of meteorological data contained in the INMET meteorological station map, the average daily precipitation measured in the town of *Caicó*, located at a distance of approximately 46.5 NM from the accident site, reached a volume of 43 mm.

In fact, the image of the PP-MCJ in flight, captured by observers near the urban perimeter of *Currais Novos*, at a distance of approximately 4 km from the site of the collision against the 230-kV LT, revealed the presence of precipitation and restricted visibility.

The messages exchanged between the PIC and his working group indicated that he was concerned about keeping his co-workers updated on the continuation of the LT inspection schedule, despite the compromised weather conditions throughout the Northeast region of Brazil.

The calling off of the initial flight of the aforementioned schedule, with the consequent return of the aircraft to *Paulo Afonso*, State of *Bahia*, on the morning of 31 May 2022 on account of weather conditions, reveals the hypothesis that the PIC felt compelled to continue the mission.

That said, it seems that the flight of the PP-MCJ outside controlled airspace and below 1,000 ft AGL, may not have been carried out in conditions of visibility equal to or greater than 1,000 m, and at flight speed sufficient for the avoidance of obstacles, as required by the ICA 100-4.

Considering that, at the point of collision, the average height of the 138-kV LT was 30 m, and that the helicopter collided with a lightning-rod cable in the upper part of the 230-kV LT, whose height was 41.66 m, one deduced there was a clear change in the usual flight profile adopted by the PIC, who used to stay approximately 5 m above and 15 m to the side of the transmission line being inspected.

With respect to the speed adopted in the inspection, the CHESF pilots reported that the aircraft speed during the aerial inspection of the 138-kV LT was estimated to be 80 kt. Therefore, one may assume that such speed hindered the early sighting of the 230-kV LT and reduced the reaction time for the necessary avoidance.

Taking as a basis the *Furnas Centrais Elétricas S.A* "Field Technical Manual", which dealt with aerial inspections of transmission lines with helicopters, one found that the referred company recommended an average speed of 30 kt. during the inspection flight. In turn, the publication "Procedures for Inspection of Electric Power Systems" recommended the maintenance of low speed so as to increase the possibility of sighting the cables, since early sight was considered more effective than speed reduction for avoidance of obstacles.

The abovementioned aspects pointed toward a scenario in which, given the compromise in horizontal visibility, the PIC moved laterally and vertically away from the 138-kV LT, and was taken by surprise by the lightning-rod cable of the 230-kV LT. It is, thus, revealed that the PIC, possibly using a speed of 80 kt, did not notice the 230-kV LT in time to avoid colliding.

In addition to the degraded conditions of horizontal visibility and the possible speed used, the camouflage effect of the vegetation on the 230-kV LT may have contributed to reducing the distance necessary to identify and avoid the obstacle in a safe and effective manner.

Regarding this subject, the article "Wire, The Invisible Enemy", published in 2017 by Flight Safety Australia, warned of the fact that the wires could disappear from the eyes and become invisible, even for a trained crew, and that several aspects can make wires invisible, such as atmospheric conditions, viewing angle; visual illusions; the pilot's visual field scanning abilities; the workload in the flight deck; and the camouflage effect of nearby vegetation.

The European EASA, in turn, published the article "Cable Collisions" in 2022, which advocated the use of an up to date version of maps showing wires and other hazards, such as natural and artificial obstacles, wind turbines included. Thus, the lack of mapping of the intersection of the 138-kV LT with the 230-kV LT on the WAC chart, GPS, and tablet used by the PIC pointed out to the inadequacy of the set of publications, maps, and software used.

Given the possibility of failures in the mapping of obstacles, the pilots would have to pay extra attention to the signage recommended by the ABNT (towers painted red/orange and electrical cables fitted with warning spheres).

With respect to signage, one observed that, within the scope of DOSPA, approximately six months before the date of the accident, messages were exchanged, reporting some non-compliances, in light of the ABNT NBR 6535:2005, such as: towers with barely visible paintings or without paintings, LT intersections without signage, as well as towers and intersections without proper inclusion on the tablet and portable GPS devices used by the pilots.

One found that in the vicinity of the intersection of the 138-kV LT with the 230-kV LT, although the electrical cables of the latter were demarcated by orange warning spheres, the 138-kV LT towers were not painted red, as prescribed in the ABNT NBR 6535:2005.

That aspect was considered relevant, since such visual stimulus would warn pilots on the imminent encounter with an obstacle (intersection with the other transmission line), especially considering that the aircraft did not have obstacle-proximity warning systems.

The Investigation Committee also identified that the failures in the 138- kV LT signage occurred despite the declared agreement between CHESF and TAESA, whereby the provider of the 230-kV LT would be responsible for signalizing the 138-kV LT towers. Thus, the lack of adequate supervision and an effective organizational process, enabling a timely feedback on information regarding LT signage, impacted the risk management of that air operation.

Although the CHESF pilots had done CRM courses, the inspectors had not participated in that type of training. Despite not being mandatory, the presence of these latter professionals in the course could have become an important tool for preventing accidents of the same nature, as there would be a standardization of attitudes and behaviors, in addition to improving the crew’s synergy.

In such scenario, one identified that pilots and line inspectors were not used to adopting any type of standardized communication (callouts) capable of optimizing the exchange of operational information between them, and that would be a crucial tool for the obtainment of an effective CRM.

Finally, since the operator did not constitute a PSAC regulated by the ANAC, the aircraft fleet operated under the rules of the RBAC-91, and implementation of an SMS was not required. From such perspective, there was not a formal safety policy for identification for the identification of hazards and management of safety risks in transmission-line inspection operations.

3. CONCLUSIONS.

3.1. Findings.

a) the PIC held a valid CMA (Aeronautical Medical Certificate);

b) the PIC held a valid HMNT rating (Single Engine Turbine Helicopter);

c) the PIC had qualification and experience for the type of flight;

d) the aircraft had a valid CVA (Airworthiness-Verification Certificate);

e) the aircraft was within the weight and balance limits specified by the manufacturer;

f) the records of the airframe and engine logbooks were up to date;

g) the helicopter was fitted with a Wire-Strike Protection System (WSPS);

h) no formal briefing was held before the mission;

i) there were active meteorological phenomena in the region where the accident occurred, such as isolated thunderstorms, cumulonimbus clouds, towering cumulus clouds, as well as rain showers with restricted visibility;

j) the aircraft was performing a flight for inspection of the CHESF (*Companhia Hidro Elétrica do São Francisco*) Company’s transmission lines;

k) the WAC 3018 Chart used in the inspection was out of date;

l) the intersection of the 138-kV LT with the 230-kV LT was not mapped in any of the resources being used (WAC chart, GPS, and tablet);

m) the 138-kV LT towers were not painted red, as required by the ABNT NBR 6535:2005;

n) the speed normally used in the operation was 80 kt, a fact that reduced the reaction-time to avoid obstacles;

o) during the inspection of the 138-kV LT near the town of *Currais Novos*, there was a collision with the 230-kV LT;

p) after the collision, the aircraft fell into a dam and submerged;

q) the aircraft was destroyed;

r) the PIC and both inspectors suffered fatal injuries.

3.2. Contributing factors.

Communication – undetermined.

During LT-inspection flights, pilots and inspectors would not make use of any type of standardized communication (callout) capable of optimizing the exchange of operational pieces of information, especially those proper for risk situations, such as proximity to obstacles, including intersections of transmission lines.

Adverse meteorological conditions – a contributor.

In the region of the accident, at the approximate time of the occurrence, there was presence of significant meteorological phenomena, such as TCU clouds, precipitation, and restricted visibility, which reduced the possibility of sighting the 230-kV LT in a timely manner.

Crew Resource Management – undetermined.

Although CHESF pilots underwent CRM training, the lack of participation of LT inspectors in that training may have affected the use of human resources available for the operation of the aircraft, especially in relation to the communication between members of the crew.

Organizational culture – undetermined.

In the phase of preparation for the flight, briefings were usually held by means of e-mails addressed to the pilots. Such briefings did not have considerations related to the safety of operations. Likewise, debriefings were not normally held, except in some informal and exceptional situations.

These informally-adopted procedures point towards an ineffective safety culture, since issues relevant to flight compliance, notably those relating to operational safety, would not be dealt with effectively.

Piloting judgment – undetermined.

Considering that, according to reports, the PP-MCJ maintained a speed of 80 kt. during the LT-inspection flight, one assumes that such fact may have hindered the early sighting of the 230-kV LT and the timely avoidance of the obstacle against which the helicopter collided.

Motivation – undetermined.

Bearing in mind that, at the beginning of the operation on 31 May 2022 the prevailing meteorological conditions influenced the flight schedule planned for the week in which the accident occurred, and also that the messages exchanged between the PIC and his working group showed a concern to keep the crew updated on the continuation of the LT-inspection schedule despite the compromised weather conditions, one cannot rule out the possibility that self-imposed pressure may have reinforced the team's motivation to operate in spite of the known restrictions to visibility.

Perception – undetermined.

It is plausible that there has been a reduction in the PIC's situational awareness, impairing his ability to recognize and understand the risks arising from an aerial operation in a condition of degraded visibility, as well as his ability to project the consequences of those risks.

Flight planning – a contributor.

There was inadequacy in the work of preparation for the flight, as there was no prior knowledge of all the operational conditions along the route, such as the unmarked intersection of the CHESF's with TAESA's transmission lines.

Decision-making process – a contributor.

In spite of the presence of meteorological phenomena in the region where the accident occurred, the decision made to continue the mission revealed flaws in the perception, analysis, and selection of alternatives appropriate for the situation experienced.

Organizational processes – a contributor.

Near the intersection of the 138-kV LT with the 230-kV LT, the investigators found that, even though the 230-kV LT electrical cables were signalized by orange spheres, the 138-kV LT towers were not painted in red, as required by the ABNT NBR 6535:2005.

The deficiencies observed in the signage of the 138-kV LT occurred despite the declared agreement between CHESF and TAESA, whereby the 230-kV LT providing company would be responsible for signalizing the 138-kV LT towers. Thus, the lack of adequate supervision and an effective organizational process, which would have enabled a timely feedback of information concerning the LT signage, affected the risk management of the air operation in question.

Support systems – a contributor.

There was lack of organizational support for providing the pilots with up-to-date information on the location of intersections of transmission lines in the accident region.

Despite availability of the WAC 3018, 6th edition (year 2020), the out-of-date chart found on board the PP-MCJ was from 2004, and did not feature the intersection of the transmission lines. Likewise, the tablet and the portable GPS equipment did not contain the required up-to-date information.

4. SAFETY RECOMMENDATIONS

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

To Brazil's National Civil Aviation Agency (ANAC):

A-069/CENIPA/2022 - 01 **Issued on 05/16/2024**

A the relevance of issuing safety-focused guidelines on the activity of transmission lines aerial inspection, taking into account international guidelines and studies published on the subject.

A-069/CENIPA/2022 - 02 **Issued on 05/16/2024**

Disseminate the lessons learned from this investigation to the CHESF Company (*Companhia Hidro-Elétrica do São Francisco*), so that the referred operator can apply the best practices during operations for inspection of transmission lines.

A-069/CENIPA/2022 - 03 **Issued on 05/16/2024**

Disseminate the lessons learned from this investigation to companies dealing with aerial inspections, with the purpose of alerting them of the risks arising from deficient signage of overhead transmission lines, based on the provisions of the ABNT NBR 6535:2005.

To Brazil's National Electric Energy Agency (ANEEL):

A-069/CENIPA/2022 - 04 **Issued on 05/16/2024**

Ensure the adequacy, on the part of concessionaires of overhead transmission lines operating in different regions of the country, of the criteria established in the ABNT NBR 6535:2005.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

After the accident, the towers of the 138-kV LT were signalized by means of painting near the intersection with the 230-kV LT, as recommended in the ABNT NBR 6535:2005 (Figure 39).

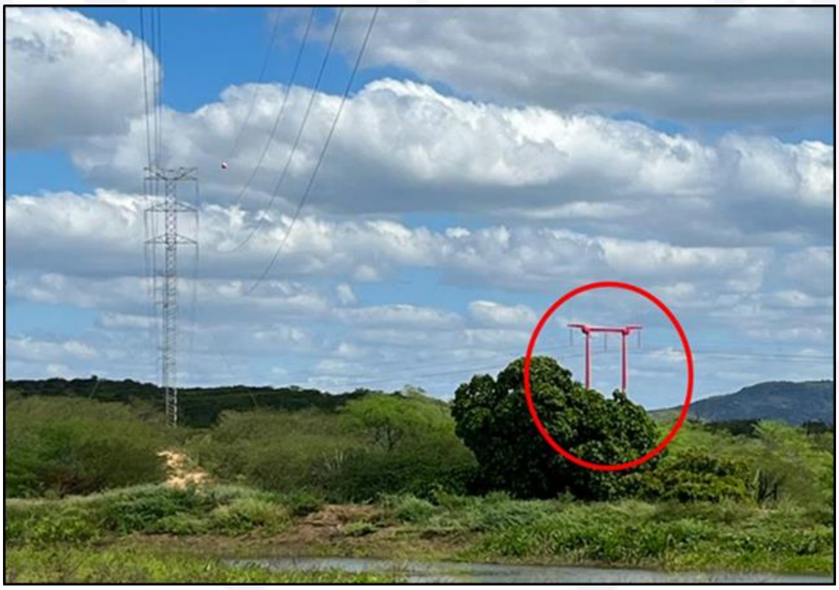

Figure 39 - Painting of 138-kV LT supports (towers), after the accident.

The CHESF, through *Paulo Afonso*'s Aviation Division (DOSPA) did the following:

- undertook studies, with the purpose of updating the criteria and operational conditions required for the conduction of VFR flights with helicopters in the inspection of transmission lines. The study addressed, among other aspects, the minimum atmospheric conditions for the execution of aerial inspections, the minimum and maximum speed limits, altitude of the flight and distances from the LT axis, conditions for leaving and entering the LT lanes, and minimum horizontal and vertical limits of visibility;

- in the planning of aerial inspections, a briefing was included involving pilots and line inspectors before each segment of flight, with the aim of comparing the data entered in the GPS and in navigation charts for the transmission line to be inspected, with emphasis on the intersections of transmission lines, obstacles, and changes of direction along the route.

DOSPA, in coordination with the georeferencing sector of the CHESF Company:

- updated the location of the intersections of CHESF's with TAESA's transmission lines on the GPS equipment made available to its pilots and line inspectors;

- implemented an alert system in the GPS equipment used by CHESF pilots, with aural and light warnings concerning proximity of intersections of transmission lines;

- introduced protocols, regulating the update of data relating to the signage of transmission line intersections, based on information obtained by line inspectors during inspection flights;

- included CHESF transmission lines in the georeferenced maps on tablets used by pilots and line inspectors; and

- established protocols for the analysis of contingent non-conformities or incidents verified during inspections, documenting and forwarding them to the various CHESF sectors interested in the matter, for the taking of necessary measures.

On May 16th, 2024.